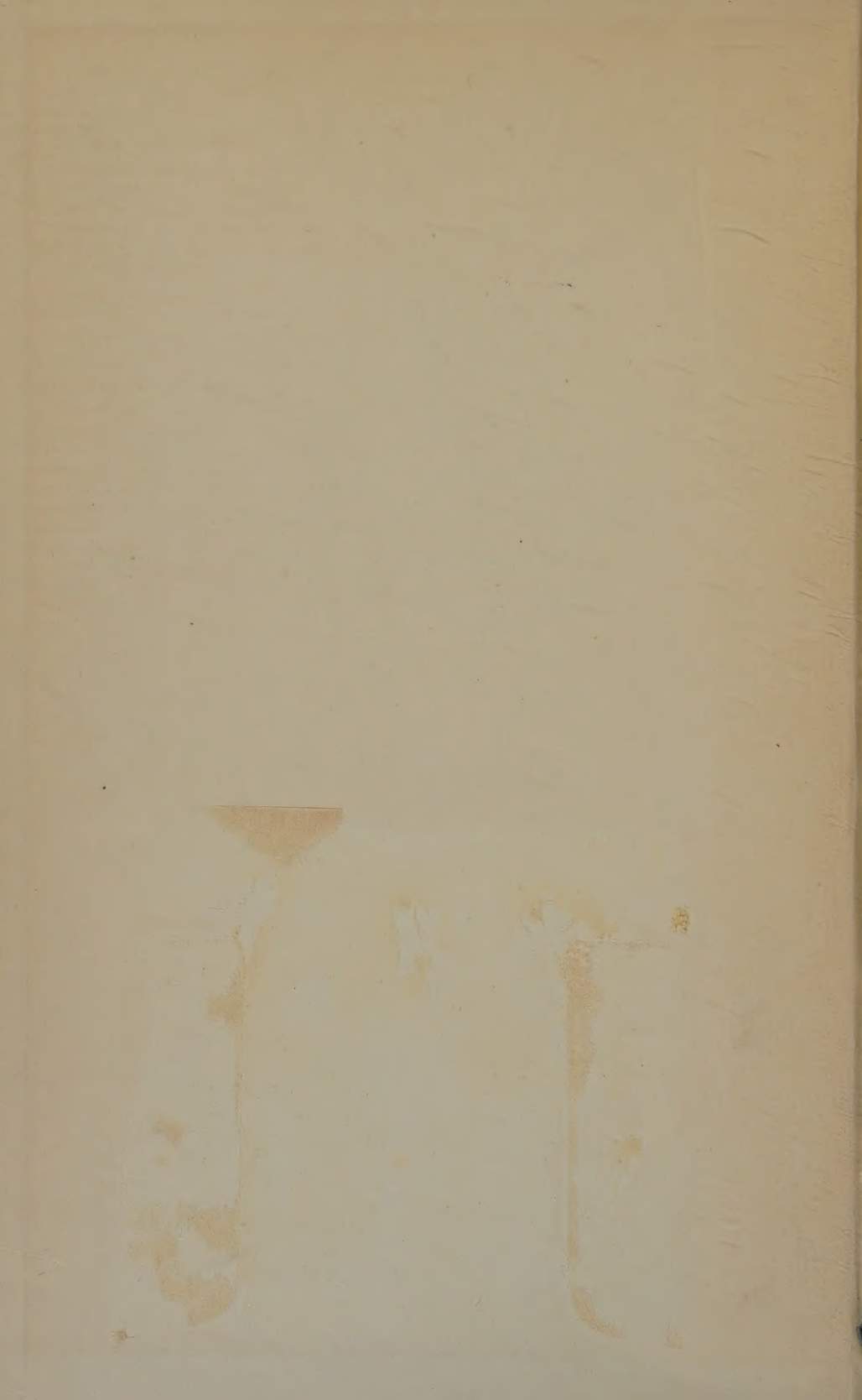
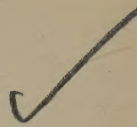




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ANNUAL REPORT OF THE
BOARD OF REGENTS OF
THE SMITHSONIAN
INSTITUTION

SHOWING THE
OPERATIONS, EXPENDITURES, AND
CONDITION OF THE INSTITUTION
FOR THE YEAR ENDED JUNE 30

1945

Withdrawn



(Publication 3817)

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1946

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THE SMITHSONIAN INSTITUTION

June 30, 1945

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*Now on war duty.

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*Now on war duty.

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*Now on war duty.

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Acting Chief Clerk.—F. E. GASS.

NATIONAL ZOOLOGICAL PARK

Director.—WILLIAM M. MANN.

Assistant Director.—ERNEST P. WALKER.

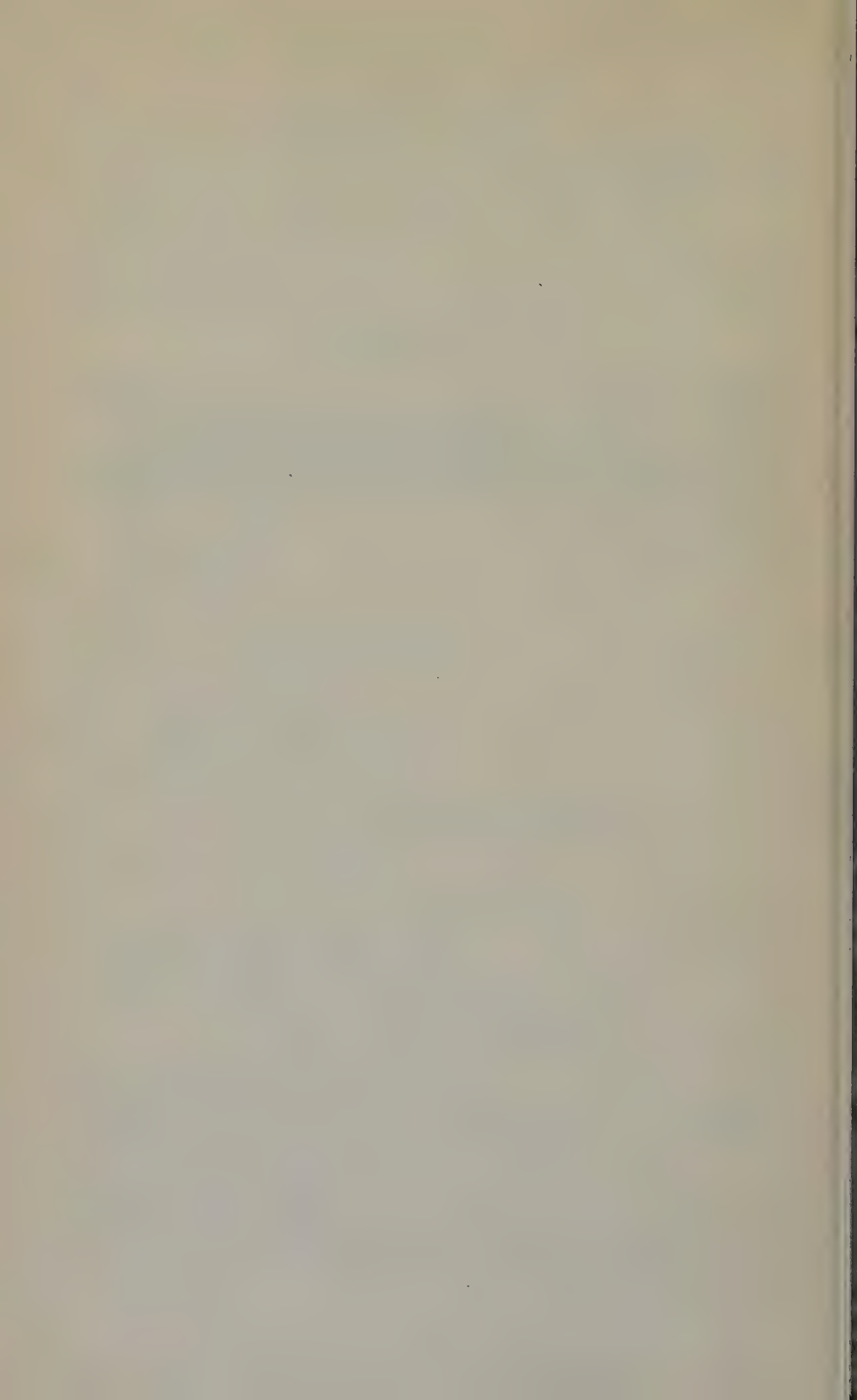
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*Now on war duty.



REPORT OF THE SECRETARY OF THE SMITHSONIAN INSTITUTION

ALEXANDER WETMORE

FOR THE YEAR ENDED JUNE 30, 1945

To the Board of Regents of the Smithsonian Institution.

GENTLEMEN: I have the honor to submit herewith my report showing the activities and condition of the Smithsonian Institution and the Government bureaus under its administrative charge during the fiscal year ended June 30, 1945. The first 14 pages contain a summary account of the affairs of the Institution; it will be noted that many activities usually included in this section are missing, wartime conditions again having forced their suspension. Appendixes 1 to 10 give more detailed reports of the operations of the National Museum, the National Gallery of Art, the National Collection of Fine Arts, the Freer Gallery of Art, the Bureau of American Ethnology, the International Exchanges, the National Zoological Park, the Astrophysical Observatory, the Smithsonian library, and of the publications issued under the direction of the Institution. On page 115 is the financial report of the executive committee of the Board of Regents.

As stated in last year's report, Dr. Charles G. Abbot, Secretary of the Institution since 1927, resigned on June 30, 1944, in order to devote himself to his researches in solar radiation. Having been Assistant Secretary of the Institution since 1925, by instruction of the Executive Committee I took over the duties of the position as Acting Secretary until the next meeting of the Board of Regents on January 12, 1945, when I was elected Secretary. I am fully mindful of the honor done me by the Board, as well as of the great responsibility devolving upon one called upon to direct the multitudinous and varied activities of such a large organization as the Institution has grown to be.

Next year, the Smithsonian will celebrate its one-hundredth anniversary, so that for 99 years its officials and staff have devoted their best efforts to making it in very fact what the founder, James Smithson, desired, namely, an institution for the increase and diffusion of knowledge among men. Starting with only the Institution proper housed in a single building, the organization has developed and expanded its fields of activity until it now directs six Government bureaus, as well as the privately endowed Freer Gallery of Art, and occupies five

buildings on the Mall, besides the numerous buildings of the National Zoological Park in northwest Washington. From a single series, Smithsonian publications have expanded to include nine regular series and four others issued at infrequent intervals.

In promoting the increase of knowledge, the Institution conducts and sponsors original researches and scientific explorations, mainly in the fields of anthropology, biology, geology, and astrophysics; the diffusion of knowledge is accomplished through the publications just mentioned, through museum and art gallery exhibits, through the International Exchanges (of scientific and governmental publications), through radio programs and popular science news releases, and through answering the scientific inquiries of thousands of correspondents each year.

Throughout Smithsonian history the basic principle that has underlain its scientific work is that researches shall be prosecuted for the new knowledge to be gained alone, without regard to its possible economic usefulness. This simple principle has enabled the Institution to accomplish much more in the way of new additions to existing knowledge than might have been expected with its limited financial resources, and it is the intention to continue this type of operation.

I assumed the secretaryship in the midst of the trying times of World War II. A large proportion of the Institution's normal activities in research, exploration, and publication had been suspended so that the staff could devote itself to aiding the Army and Navy in the prosecution of the war. Some of this work is described later in this report. At the close of the fiscal year, however, victory had been achieved in Europe, and it was beginning to be apparent that the Japanese could not resist much longer. My first duty, therefore, will be to plan the orderly resumption of normal Smithsonian work, at the same time taking stock of the Institution's position in the light of postwar conditions. Two of the major problems facing the Institution at the close of the war are the inadequacy of the present buildings for the National Museum, and the need for more personnel in the scientific, clerical, and custodial categories. Steps to remedy both of these conditions are under consideration.

One of my first concerns was to review the relationship of the Institution with the Series Publishers, Inc., who published the Smithsonian Scientific Series. This set of 12 volumes was written and edited by members of the Institution's staff, and published and sold under contract by the above corporation, the Institution receiving author's royalties on all sales. Over the past several years numerous complaints had reached the Institution regarding the selling methods of the publisher's agents. I held a series of conferences with the officials of the company, as a result of which it is believed the causes for complaint have been largely eliminated.

SPECIAL WARTIME ACTIVITIES

Technical information to armed forces.—Probably the Institution's most useful wartime function has been to furnish technical information requested by the Army, Navy, and war agencies. During the first years of the war information was urgently needed on the geography, peoples, disease-bearing insects and other animals, and other features of many little-known war areas, particularly in the Pacific theater. As many members of the Institution's scientific staff had visited or studied these regions, they were called upon with increasing frequency to furnish such information. Records kept by the Smithsonian War Committee showed more than 2,000 such requests during the first 2 years of war. As the Pacific war moved westward, however, first-hand information became available to the Army and Navy, and calls upon the Institution's staff during the past year began to diminish, although several staff members continued to be in almost continuous conference with Army and Navy officials.

Ethnogeographic Board.—The same sequence of events occurred in the case of the Ethnogeographic Board, a nongovernmental agency created cooperatively by the Smithsonian Institution, the National Research Council, the American Council of Learned Societies, and the Social Science Research Council, to act as a clearinghouse for anthropological and geographic information needed by the Army and Navy. During the earlier stages of the war the Board was called upon continually for information, reports, and assistance, and its very extensive file of American experts in many branches of science was in constant use. Around July 1, 1944, however, the need for such service began to taper off, and Dr. William Duncan Strong, the Director, returned to Columbia University to resume his duties as professor of anthropology. The Board was kept in operation under the direction of Dr. Henry B. Collins, Jr., of the Bureau of American Ethnology, who had assisted Dr. Strong from the beginning. Its services were in demand, though to a lesser extent, throughout the year.

Improvement of cultural relations with the other American republics.—A wartime service which the Institution was unusually well fitted to take part in was the Government's program for the improvement and extension of cultural relations with the other American republics. A number of projects in this field were undertaken soon after the beginning of the war, and these have been carried forward during the past year. The monumental Handbook of South American Indians, of which 50 percent of the authors are scientists of the other American republics, progressed satisfactorily under the continued guidance of Dr. Julian H. Steward. Volumes 1 and 2 were in proof, and volumes 3 and 4 went to the printer toward the close of the year. The manuscript of the fifth and last volume was expected to be com-

pleted early in the coming year. The editorial costs of the Handbook, which will appear as a Bulletin of the Bureau of American Ethnology, have been defrayed by the Department of State.

The Institute of Social Anthropology, set up in 1943 under the directorship of Dr. Steward to carry out cooperative training in anthropological teaching and research with the other American republics, continued its work in Mexico jointly with the Escuela Nacional de Antropología of the Instituto Nacional de Antropología e Historia. Two members of the Institute's staff taught at the Escuela and, during the last half of the year, directed field research among the Tarascan Indians. In Perú, staff members studied Moche, an Indian community on the north coast, and supervised a field survey of the central Highlands of Perú by representatives of the Museos Históricos. In Brazil, teaching and research in Brazilian social anthropology were planned in cooperation with the Escola Livre de Sociologia e Política of São Paulo.

The third part of a "Checklist of the Coleopterous Insects of Mexico, Central America, the West Indies, and South America," by Dr. R. E. Blackwelder, appeared during the year. As stated in previous reports, this published list of one of the largest and most important groups of insects will be an invaluable aid in future entomological research in the Americas.

In addition to these major projects several members of the staff conducted field work in various South and Central American countries in cooperation with scientists of those countries.

Return of evacuated collections.—Early in the war many of the priceless and irreplaceable historical and scientific materials in the national collections were removed to a place of safety in anticipation of possible bombings of American cities. By November 1944 this potential danger was considered to be negligible, and all the evacuated material was brought back to the Institution. The specimens so handled occupied 21,000 cubic feet of space and weighed some 117,500 pounds. The transfer was made without damage in spite of the fact that many of the specimens were fragile and difficult to pack and to handle. Among the materials safely transported both ways were thousands of type specimens of mammals, birds, fishes, insects, plants, and other life forms, which are of vital importance to science. Other priceless specimens to make the trip were the original Star Spangled Banner, George Washington's field kit, and many other tangible evidences of America's past struggles to win and preserve her freedom. The scientific and historical collections in American institutions and museums assume an ever greater importance in view of the destruction of a great many such collections in Europe.

Smithsonian War Background Studies.—The series of publications started early in the war to present authentic information on the peoples, geography, history, and other features of war areas, entitled "War Background Studies," was concluded during the year. Details of the series are given later in this report, and I will say here only that the demand for the books far exceeded the expectations of the Institution, and it was found necessary to reprint all of them, some a number of times, not only for distribution by the Institution, but also for the official use of the Army and Navy. The total number of copies printed for both the Institution and the armed services was 632,225.

SUMMARY OF THE YEAR'S ACTIVITIES OF THE BRANCHES OF THE INSTITUTION

National Museum.—All possible efforts of the staff were concentrated on projects related to the prosecution of the war, though these naturally lessened toward the close of the year. Several members of the staff worked in connection with the Department of State's program for cultural cooperation with the other American republics, involving travel and study in Mexico, Haiti, Chile, and Panamá. During the year, 232,822 specimens were added to the collections, bringing the total number of catalog entries to 18,151,400. Worthy of special mention among the new accessions were the following: In anthropology, 5,677 specimens from Indian village sites in Scott and Lane Counties, Kans., a large number of specimens from various islands in the Pacific, and the valuable Arthur Michael collection of early American silver; in biology, a collection of 600 birds from Panamá, 700 reptiles and amphibians from the Indo-Pacific region, the Dayton Stoner collection of Scutelleroidea, 25,000 mollusks from the Perlas Islands, Panamá, and two lots of plants from Colombia totaling 3,720 specimens; in geology, a number of rare and valuable gems and minerals, including the finest specimen so far recovered of the new mineral brazilianite, several meteorites, including the 1,164-pound Drum Mountain, Utah, meteorite, and 10,000 fossil specimens collected in the Paleozoic of the southern Appalachians by Dr. Charles Butts; in engineering and industries, the first experimental jet-propelled plane built in this country, a well-preserved 1902 Oldsmobile, and the entire equipment and furnishings of an Old World apothecary shop of the period 1750; in history, a series of 50 bronze statuettes by Max Kalish of distinguished Americans, known as The Living Hall of Washington, 1944. The total number of visitors to the Museum during the year was 1,730,716, an increase over last year of 197,951. The year's publications included 1 Bulletin, 1 Contribution from the National Herbarium, and 18 Proceedings papers. Among the im-

portant staff changes were the advancement of John E. Graf from Associate Director of the Museum to Assistant Secretary of the Smithsonian Institution; the appointment of Dr. Raymond M. Gilmore as associate curator in the division of mammals, William E. Hoffmann, associate curator in the division of insects, Robert A. Elder, Jr., as assistant curator in the division of ethnology, and Mrs. Mildred S. Wilson as assistant curator in the division of marine invertebrates.

National Gallery of Art.—The year's attendance at the Gallery was the largest since it was opened in 1941, the total being 2,078,739. Approximately 35 percent of these were men and women in the armed services. Sunday night openings with free concerts continued throughout the year with undiminished popularity. In October 1944 the Gallery published a book, *Masterpieces of Painting from the National Gallery of Art*, which contained 85 color reproductions of paintings in the collections. The public demand was so great that a second edition was being printed at the close of the year. A contract was entered into for the completion of six new galleries for exhibition of recent acquisitions of paintings and sculpture. All the works of art in protective storage in North Carolina during the war were brought back to the Gallery without damage in October 1944. Gifts included 80 important Italian, French, and Dutch paintings and 26 pieces of sculpture from Samuel H. Kress and the Samuel H. Kress Foundation, and a number of other paintings from various donors, as well as 1,740 prints and drawings from Lessing J. Rosenwald, and others from a number of donors. Twelve special exhibitions were held at the Gallery, including several of war paintings. Traveling exhibitions from the Index of American Design and the Rosenwald collection of prints were sent to art institutions in various parts of the country. The Gallery tours attracted more than 15,000 people, and nearly 27,000 attended the daily 10-minute lectures on the "Picture of the Week."

National Collection of Fine Arts.—The twenty-second annual meeting of the Smithsonian Art Commission was held on December 5, 1944, the annual meetings scheduled for the 2 previous years having been canceled on account of transportation conditions. A number of oil paintings and other art works that had been submitted since the last meeting in 1941 were accepted. The Commission adopted resolutions on the death of three former members, John E. Lodge in 1942, and Charles L. Borie and Dr. Frederick P. Keppel in 1943. Officers elected for the coming year were: Paul Manship, chairman; Frank Jewett Mather, Jr., vice chairman; and Dr. Alexander Wetmore, secretary. Seven miniatures were acquired through the Catherine Walden Myer fund. A number of paintings were lent to other organizations, including two to the White House, one of these—Max Weyl's "Indian Summer Day"—to be hung in President Truman's

study. Eight special exhibitions were held, as follows: A selection of paintings from the William T. Evans collection of American paintings; group of portraits by Enit Kaufman, called "The American Century"; the Seventh Metropolitan State Art Contest; miniatures by the Pennsylvania Society of Miniature Painters; water colors of Latin America by Carl Folke Sahlin; paintings by modern Cuban painters; paintings and sculpture by members of the Society of Washington Artists; and drawings presented to the United States by the French Republic in 1915.

Freer Gallery of Art.—Additions to the collections included Egypto-Arabic bookbinding, Chinese bronze, Arabic and East Persian calligraphy, Chinese and Persian ceramics, Persian manuscript, Persian and Veneto-Islamic metalwork, Chinese, Indian, and Persian painting, Chinese sculpture, and Chinese silver. Curatorial work of the staff was devoted to the study of new acquisitions and to general research work within the collections, as well as to the preparation of material for publication. Reports were made on more than 2,000 objects submitted for examination by other institutions and by individuals. Work connected with the war included assistance given the Office of War Information by a staff member 4 days a week for 6 months, and the revision of official Government publications on China and Japan. The Gallery has heretofore been open to the public every day except Monday, but beginning January 29, 1945, it was open 7 days a week. The year's visitors totaled 72,186. Staff members gave 12 lectures during the year before various organizations. Among the changes in personnel were the appointment of Richard Ettinghausen as associate in Near Eastern art, and the detachment from the Gallery of John A. Pope, associate in research, for active duty as Captain, United States Marine Corps Reserve.

Bureau of American Ethnology.—Dr. M. W. Stirling, Chief of the Bureau, devoted 5 months to continuing the work of the Smithsonian Institution-National Geographic Society archeological project in southern Mexico. Reconnaissance work located a number of archeological sites, and excavations were conducted on a large earth mound covering a complex stone-masonry structure in Chiapas near the town of Ocozocoautla. A new large site of the La Venta culture was discovered on the Río Chiquito in southern Veracruz. It contained two large mound groups and a number of carved monuments, including the two largest La Venta colossal heads yet found. Dr. John P. Harrington spent a large part of his time in translating letters and documents in obscure languages for the Office of Censorship. In addition, he prepared 12 articles on American Indian linguistic subjects. Dr. Frank H. H. Roberts, Jr., continued his studies of the Folsom material obtained from the Lindenmeier site in northern Colorado, including comparisons with artifacts from other early sites in the New World.

Dr. Roberts served as liaison between the Smithsonian Institution and the Committee for the Recovery of Archaeological Remains, an organization representing several societies interested in the preservation of aboriginal materials that are in danger of being lost through the flooding of river areas by power-dam construction. Dr. Henry B. Collins, Jr., served as Director of the Ethnogeographic Board after the resignation of Dr. Strong. He also attended a meeting in Montreal to organize the Arctic Institute of North America, formed to promote scientific research in Alaska, Canada, and Greenland; later, as one of the governors of the Institute, he attended other meetings in Montreal to formulate plans for its operation. Dr. William N. Fenton continued his work as research associate of the Ethnogeographic Board, completing six reports on a survey of Army training programs in American universities. Toward the end of the year Dr. Fenton resumed his studies on the Iroquois Indians, visiting the Six Nations Reserve near Brantford, Canada. Dr. H. G. Barnett continued his studies of the general problem of cultural change, especially as related to Indian tribes of California, Oregon, and Washington, and one publication on this subject was nearly completed. Dr. Gordon R. Willey devoted a large part of the year to editorial work on the *Handbook of South American Indians*. He also studied and completed a report on several large collections of archeological specimens from southern Florida. The Institute of Social Anthropology, an autonomous unit of the Bureau under the directorship of Dr. Julian H. Steward, continued its program of cooperative teaching and field researches in Mexico and Perú, and an agreement was reached during the year for similar work in Brazil. Under Dr. Steward's editorship, the *Handbook of South American Indians* progressed materially. Volumes 1 and 2 were in proof, volumes 3 and 4 were completed and sent to the printer, and the fifth and last volume was in the final stages of preparation.

International Exchanges.—The International Exchange Service is the official agency of the United States for the exchange of governmental and scientific publications between this country and all other countries. The number of packages passing through the Exchange Service during the year was 386,758, with a total weight of 211,160 pounds. The franking privilege in transmitting packages through the mails was discontinued by the Post Office Department during the year, resulting in an increase in the costs and work involved in handling such packages. Although the war in Europe ended toward the latter part of the year, it was not possible to resume exchange consignments to liberated countries by the close of the year. Accumulations for France, Italy, and Belgium, however, were forwarded through the Office of War Information, and those for Sweden, Palestine, and Egypt through the United States Despatch Agent in New York.

Regular consignments were sent during the year to all countries in the Western Hemisphere, and in the Eastern Hemisphere to Great Britain and Northern Ireland, Republic of Ireland, Portugal, Union of Soviet Socialist Republics, Africa, India, Australia, and New Zealand. Shipments to other countries will be resumed as soon as conditions permit.

National Zoological Park.—The exhibition collection of animals has been maintained in good condition during the year, but to accomplish this with the serious shortage of personnel that prevailed, some phases of the care of the Park had to be neglected, and no improvements could be made. Increased personnel is the most urgent need of the Park. Visitors to the Zoo numbered 2,355,514 for the year, a considerable increase over last year. Among the interesting specimens presented to the Park were a pair of Solomon Islands cockatoos, a red-sided lory, three wallabies, a pigmy galago and two green fruit pigeons from the Gold Coast of Africa, a collection of brilliant cage birds from Costa Rica, and a pair of the rare antelope, *Oryx beatrix*, from Saudi Arabia. A list of the donors of specimens will be found in the full report on the Zoo, appendix 7. Notable among the births at the Park were a hybrid gibbon, a giraffe, and four chinchillas. Altogether, 58 mammals were born, and 21 birds were hatched. At the close of the year, the collection contained 2,623 individuals representing 686 species.

Astrophysical Observatory.—Dr. C. G. Abbot, for many years Director of the Observatory, retired from administrative duties on June 30, 1944, but will continue his investigations as research associate. L. B. Aldrich was named Acting Director, and on April 16, 1945, succeeded to the directorship. In the Division of Astrophysical Research two sets of experiments were carried out at the request of the Office of the Quartermaster General to determine the surface temperatures attained by various samples of military clothing under conditions similar to those of actual field use. Toward the close of the year another study was undertaken for the Quartermaster General of the radiation from sun and sky at Camp Lee, Va., in connection with tests being made at the camp. Much time was devoted to a compilation of all solar-constant values for the period October 1939 to January 1945, an extension of the table published in volume 6 of the Observatory's Annals. A study of these values, which cover a complete double sunspot period, showed a diametrically opposite relationship between solar-constant values and sunspot numbers in the two halves of the period. Studies were continued of the effects of solar-radiation changes upon atmospheric circulation and related problems. Observations of the solar radiation were continued at the three field stations. In the Division of Radiation and Organisms, war researches on deterioration of cloth, cardboard, and wire insulation by molds and by ultraviolet light were concluded. The termination of

this emergency work permitted the resumption of studies on photosynthesis and on the wave-length effects of light on growth. Work was also taken up on the influence of light on the respiration of the grass seedling, the course of development of the grass seedling as influenced by various factors, particularly radiant energy, and the reducing sugar content of etiolated barley seedlings as influenced by light.

THE ESTABLISHMENT

The Smithsonian Institution was created by act of Congress in 1846, according to the terms of the will of James Smithson, of England, who in 1826 bequeathed his property to the United States of America "to found at Washington, under the name of the Smithsonian Institution, an establishment for the increase and diffusion of knowledge among men." In receiving the property and accepting the trust, Congress determined that the Federal Government was without authority to administer the trust directly, and, therefore, constituted an "establishment" whose statutory members are "the President, the Vice President, the Chief Justice, and the heads of the executive departments."

THE BOARD OF REGENTS

During the year the following changes occurred in the personnel of the Board of Regents:

January 20, 1945, Harry S. Truman assumed office as Vice President of the United States, vice Henry A. Wallace, and thus became, ex officio, a member of the Board of Regents. On April 12, 1945, Mr. Truman acceded to the Presidency, on the death of President Roosevelt, the resulting vacancy in the office of Vice President creating a vacancy on the Board of Regents.

March 1, 1945, Senators Wallace H. White, Jr., of Maine, and Walter F. George, of Georgia, were appointed regents to succeed the late Senator Charles L. McNary and former Senator Bennett Champ Clark, respectively.

January 29, 1945, Representative B. Carroll Reece, of Tennessee, was appointed a regent to succeed former Representative Foster Stearns.

The roll of regents at the close of the fiscal year, June 30, 1945, was as follows: Harlan F. Stone, Chief Justice of the United States, Chancellor; members from the Senate—Alben W. Barkley, Wallace H. White, Jr., Walter F. George; members from the House of Representatives—Clarence Cannon, Edward E. Cox, B. Carroll Reece; citizen members—Frederic A. Delano, Washington, D. C.; Roland S. Morris, Pennsylvania; Harvey N. Davis, New Jersey; Arthur H.

Compton, Illinois; Vannevar Bush, Washington, D. C.; and Frederic C. Walcott, Connecticut.

Proceedings.—The annual meeting of the Board of Regents was held on January 12, 1945, with the following members present: Chief Justice Harlan F. Stone, Chancellor; Representative Clarence Cannon; citizen regents Harvey N. Davis, Arthur H. Compton, and Vannevar Bush, and the Acting Secretary, Dr. Alexander Wetmore.

The Acting Secretary presented the annual report covering the activities of the parent institution and of the several Government branches, including the financial report of the executive committee, for the fiscal year ended June 30, 1944, which was accepted by the Board. The usual resolution authorizing the expenditure by the Secretary of the income of the Institution for the fiscal year ending June 30, 1946, was adopted by the Board.

The annual report of the Smithsonian Art Commission was presented by the Acting Secretary and accepted by the Board. The Commission on December 5, 1944, held its first meeting since the commencement of the war, and took action on the acceptance of numerous works of art which had been offered to the Institution in the interim, including a number of paintings which had been purchased by the Council of the National Academy of Design from the fund provided by the Henry Ward Ranger bequest and were eligible for acquisition by the National Collection of Fine Arts under the provisions of this bequest. Vacancies on the Commission were caused by the death of Charles L. Borie, Jr., John E. Lodge, and Frederick P. Keppel, and the Commission recommended to the Board the names of George Hewitt Myers, Archibald G. Wenley, and Robert Woods Bliss to fill these vacancies, the recommendations being approved by the Board. Paul Manship was elected chairman of the Commission to succeed Mr. Borie, and Dr. Alexander Wetmore was elected secretary.

In connection with the proposed centennial celebration of the Institution during August 1946, the appointment of the following committees was announced: By the Chancellor, regents Bush, Delano, and Walcott, with the Chancellor as chairman; by the Acting Secretary, Messrs. Graf, Clark, True, and Roberts, with the Acting Secretary as chairman.

A report was received from the special committee of regents appointed at the last annual meeting of the Board to consider the policy of the Institution with respect to the tenure of office and retirement provisions for the office of Secretary, and the several recommendations made by the special committee were adopted by the Board. In accordance with this procedure, the resignation of Dr. Charles G. Abbot as Secretary was accepted, and he was, by resolution, appointed as research associate of the Institution.

The Board then adopted a resolution electing Dr. Alexander Wetmore as Secretary of the Smithsonian Institution.

Resolutions were adopted by the Board regarding a study of the business management and future policies of the Institution.

In a special statement Dr. Wetmore outlined to the Board recent activities carried on by all branches of the Institution.

FINANCES

A statement on finances will be found in the report of the executive committee of the Board of Regents, page 115.

CENTENNIAL CELEBRATION

August 10, 1946, will be the one-hundredth birthday of the Smithsonian Institution. On that same date in 1846 the act was signed that established the Institution, culminating 8 years of debate in Congress as to how best to carry out the wishes of James Smithson, the English scientist who bequeathed his fortune to the United States of America "to found at Washington, under the name of the Smithsonian Institution, an establishment for the increase and diffusion of knowledge among men." In a human life the passage of a century brings venerable old age and usually the end of useful activity; for an organization such as the Smithsonian it merely marks the end of a conventional period of time and the beginning of a new period which must see the Institution continue to develop and expand in the furtherance of its stated objectives.

Such an anniversary clearly calls for a fitting celebration, and for the past several years plans have been shaping up. About the time these plans would have crystallized, however, the Nation was forced to go to war, and all such matters had to be held in abeyance. With the end of the war definite plans will be announced by the committee of the Board of Regents appointed to select the final form that the celebration will take.

THIRTEENTH ARTHUR LECTURE

Under the terms of the will of the late James Arthur, of New York, the Smithsonian Institution received in 1931 a fund, part of the income from which should be used for an annual lecture on some aspect of the science of the sun.

The thirteenth Arthur lecture was given by Matthew W. Stirling, Chief of the Bureau of American Ethnology, on January 17, 1945, under the title "Sun Lore of the Indians." The lecture will be published, with illustrations, in the Report of the Smithsonian Institution for 1945.

PUBLICATIONS

One of the Smithsonian Institution's primary functions, the diffusion of knowledge, is carried out chiefly by means of its several series of publications. These record the results of original researches by members of the staff or by outside scientists working on the national collections under direction of the Institution. The Smithsonian Annual Report contains each year a selection of original or reprinted articles presenting new developments in nearly all branches of science; it continues in wide demand by librarians, teachers, and individuals interested in the progress of science. The vital importance to a nation of the vigorous promotion of science was dramatically demonstrated during World War II, and such semipopular reviews of science progress as the Smithsonian Reports have played a definite part in building the popular understanding and appreciation of science that is essential to its healthy growth.

The series of Smithsonian War Background Studies was brought to a conclusion during the year with the appearance of No. 20 on China, by A. G. Wenley and John A. Pope, and No. 21 on the Aleutian Islands, by Henry B. Collins, Jr., Austin H. Clark, and Egbert H. Walker. The widespread demand for the pamphlets continued, from Army and Navy organizations and personnel and from civilians. The largest reprint order so far received, totaling 180,000 books, was from the Army for use in orientation of officers and men transferred from Europe to the Pacific theater. The titles and authors of the entire series, which covered nearly every country and island group in the Pacific war area as well as other regions and special war topics, will be found in the report on publications, appendix 10.

Among outstanding publications of the year may be mentioned one by former Secretary C. G. Abbot on "Weather Predetermined by Solar Variation," in the Smithsonian Miscellaneous Collections; "Summary of the Collections of Amphibians Made in Mexico under the Walter Rathbone Bacon Traveling Scholarship," by Edward H. Taylor and Hobart M. Smith, and "Review of the Spider Monkeys," by Remington Kellogg and E. A. Goldman, in the Proceedings of the National Museum; and "Houses and House Use of the Sierra Tarascans," by Ralph L. Beals, Pedro Carrasco, and Thomas McCorkle, the first publication of the Institute of Social Anthropology.

A total of 56 publications were issued during the year, and 141,635 copies of publications in all series were distributed.

LIBRARY

Demands on the Smithsonian library by the Army and Navy declined as the war drew to a close. On the other hand, receipts of foreign publications began to increase toward the end of the year,

and it became apparent that some European learned societies and museums had been able to continue publication throughout the war period. The rare books and manuscripts removed from the Institution early in the war to Washington and Lee University were safely returned during the year. Usually, the need for current scientific books makes it impossible for the library to purchase the older volumes needed for reference, but this year it was fortunate in being able to acquire a considerable number of these valuable old works, some of them dating back to the seventeenth and eighteenth centuries. As usual, the Institution received a large number of gifts of publications from individuals and organizations. The library's most urgent need is relief from the overcrowding of the shelves in all the Institution's buildings. The year's accessions totaled 4,844 items, bringing the library's holdings to 918,460. New exchanges were arranged to the number of 218, and 6,671 "wants" were received. Volumes and pamphlets cataloged numbered 6,512, and loans totaled 10,833. More than 2,500 volumes were sent to the bindery.

Respectfully submitted.

A. WETMORE, *Secretary*.

APPENDIX 1

REPORT ON THE UNITED STATES NATIONAL MUSEUM

SIR: I have the honor to submit the following report on the condition and operation of the United States National Museum for the fiscal year ended June 30, 1945.

Appropriations for the maintenance and operation of the National Museum for the year totaled \$938,994, which was \$8,995 more than for the previous year.

THE MUSEUM IN WARTIME

It was with considerable relief that we were able during the year to bring back to Washington the thousands of valuable type specimens and other irreplaceable objects that early in the war had been removed from the Capital for safekeeping in the event of enemy air raids on the city. Return of this material, which aggregated more than 60 tons, was completed in November 1944, and by the end of the year most of the specimens had been reinstalled.

As in previous years since 1941, all possible efforts of the staff were concentrated on projects related to the prosecution of the war, directly or indirectly, though naturally these lessened toward the close of the year, as the end of the war became imminent. Again this year several members of the staff were called upon for work in connection with the Department of State's program for cultural cooperation with the other American republics. This entailed travel and study in Mexico and Haiti, respectively, by two Museum anthropologists, and in Chile by the curator of insects. Strategic geological work was conducted in Mexico in cooperation with the Geological Survey; and biological investigations in Panamá were made for the War Department by two Museum staff members. Others undertook specific research projects directly connected with the war and its attendant disease, food, and other problems. Still others were granted furloughs for military service or for work with the Office of Strategic Services and other war agencies. Hundreds of specimens were identified for the Army and Navy, and special attention was given to material sent in by members of the armed services from remote corners of the earth where few or no collectors had previously been. All these activities add up to considerable when their far-flung results are

actually evaluated, and the Museum staff may be justly proud of its part in the war effort, which now has ended so victoriously.

COLLECTIONS

The Museum collections were increased during the year by 232,822 specimens, which were included in 1,562 separate lots. The five departments registered specimens received as follows: Anthropology, 6,642; biology, 197,462; geology, 23,770; engineering and industries, 3,199; history, 1,749. Most of the accessions were acquired as gifts from individuals or as transfers of specimens by Government departments. The complete report on the Museum, published as a separate document, includes a detailed list of the year's accessions, but the more important are summarized below. Catalog entries in all departments now exceed 18,000,000.

Anthropology.—The largest lot of archeological material accessioned during the year consisted of 5,677 specimens excavated from Indian village sites in Scott and Lane Counties, Kans., in 1939 by Associate Curator Waldo R. Wedel. Other Kansas material included 343 archeological specimens from the collection of the late Dr. Norman L. Roberts, of Topeka. Specimens of interest from out of the country included 2 painted Neolithic jars from China and 10 Nasca and Early Chimú vessels from Perú. In the field of ethnology, the year's accessions came especially from the Northwest Pacific coast and Alaska, Micronesia, Polynesia, Solomon Islands, New Guinea, Burma, China, Ecuador (Jivaro Indians), and North America (several Indian tribes), many of them through the interest and efforts of men in the armed services. An important contribution to the Micronesian collection was a large model outrigger canoe (*baurua*) from Tarawa in the Gilbert Islands. Another interesting addition was a royal Hawaiian cape (*ahuula*), fully feathered with black and yellow feathers of the *oo* bird and red feathers of the *iwi*. An Arab costume presented to Gen. H. H. Arnold by the King of Saudi Arabia was lent to the Museum by General Arnold. The section of period art and textiles received through deposit from the Smithsonian Institution the valuable and well-known Arthur Michael collection of early American silver, representing the work of 121 silversmiths of the Colonial and Federal periods (1675–1850), among whom are John Coney and Paul Revere. This outstanding bequest was placed on exhibition in the lobby of the Natural History Building. Notable gifts to the division of physical anthropology included 22 skeletons from Amchitka Island, Aleutians, 35 embryological specimens, and the well-known skull of *Homo novusmundus* found near Folsom, N. Mex., in 1935.

Biology.—Important collections of mammals came from the Indo-Pacific region, including species heretofore unrepresented in the collections from Australia and the Philippines, and from Panamá.

A collection of nearly 600 birds came from Panamá, 500 from Ceylon, and about 100 from Admiralty Islands, the last being a region heretofore unrepresented in the Museum's collections. Other avian material received included 45 bird skins from Nissan Island, Solomons; 8 specimens of Venezuelan birds; the type of a new subspecies of blackbird, *Agelaius canthomus monensis*, from Puerto Rico; and 62 bird skins from extreme eastern Brazil.

Noteworthy additions to the herpetological collections came from Panamá, Haiti, Trinidad, Sierra Leone, Virgin Islands, Ceylon, and New Guinea. Four accessions, comprising about 700 specimens of reptiles and amphibians from the Indo-Pacific region, were received from the Naval Medical School, Bethesda, Md.

A bramble shark received during the year represents, so far as known, the only specimen of this shark in any North American museum; it was washed ashore on the California coast. Exchanges brought many valuable fish specimens to the collections, including 12 paratypes of Venezuelan fishes. Fifty-eight Cuban fishes, including 43 paratypes, were received as a gift. The largest single ichthyological addition of the year comprised 1,180 specimens collected for the Museum from the Perlas Islands, Panamá.

Most important of the year's insect accessions was the large amount of mosquito material received from various units of the Army and Navy. Aside from this, the outstanding addition of the year was the Dayton Stoner collection of Scutelleroidea, accompanied by a considerable series of Coleoptera and other insects. In addition, about 3,000 insects of all orders were collected for the Museum from the Perlas Islands, Panamá, and 1,500 from Chile. The Department of Agriculture transferred 72,000 insects to the Museum.

Six of the year's accessions brought type material of marine invertebrates, representing new species of parasitic copepods, crayfish, a parasitic isopod, and a turbellarian worm. Besides, a large collection of marine invertebrates came from the Perlas Islands, Panamá.

In mollusks, the year's largest accession, 25,000 specimens, was collected for the Museum in the Perlas Islands, Panamá. Other noteworthy molluscan additions were 200 specimens of shipworms from the Canal Zone, about 300 Mexican land, fresh-water, and marine shells, 385 land shells from Panamá, more than 600 shells from the Pacific region from the Naval Medical School, and nearly 2,900 shells from various Pacific localities received from 13 members of the armed services. Helminths added during the year included paratype and

cotype material of 10 new forms, 13 specimens from New Guinea, and 101 specimens from the Perlas Islands.

Among the echinoderms received was an example of the starfish *Linckia rosenbergi* from the South Pacific, not seen since originally described in 1866, and 85 other specimens from Biak Island, the first echinoderms ever received by the Museum from that part of the world. Thirty-four corals were received from five servicemen in the Pacific region.

Botanical material came from many parts of the world and in varying lots and quantities. Perhaps the most important accession in this field was a set of 8,000 photographs of plant types in European herbaria (mostly in the Berlin Herbarium), purchased from the Chicago Natural History Museum. Other important accessions included two lots of plants from Colombia, totaling 3,720 specimens; about 1,400 plants transferred from the United States Department of Agriculture, of which 1,360 are from northern Brazil; 111 specimens and nearly 300 photographs of type material of *Crepis* and related genera; 622 specimens of Ecuadorian trees; several sizable lots of plants from Venezuela, Mexico, Martinique and Guadeloupe, Cuba, and Texas; and 172 specimens of ferns, mostly from Pacific islands. In addition, about 6,400 plant specimens of many kinds were received in exchange with other institutions, both North and South American. Diatom material was received from two remote places: 10 samples from various deposits at Oamaru, New Zealand, and 2 samples of planktonic species from near Attu Island in the Aleutians.

Geology.—Income from the Canfield and Roebling funds continued to supply rare and valuable gems and minerals for the collections. The finest specimen so far recovered of the new mineral brazilianite, from Arrasuahy, Brazil, was among the four accessions credited to the Canfield fund during the year. Through the Roebling fund 10 accessions of minerals and gems were recorded. Among the many gifts were 16 different-colored jade rings and a synthetic emerald of 90 points, and from the United States Customs Service came a series of 160 cut stones. The mineral collections also benefited by a number of very fine gifts, outstanding among which were the James Douglas collection of copper minerals from Bisbee, Ariz., and the T. Sterry Hunt mineral collection. Several meteorites were added, including the 1,164-pound Drum Mountain, Millard County, Utah, meteorite (through the Roebling fund) and an 81-pound mass of the Odessa meteorite. A suite of 22 nickel ores came from New Caledonia.

In the field of invertebrate paleontology and paleobotany seven times as many specimens were received as for the previous year, and several accessions were noteworthy. Transferred from the United States

Geological Survey was the extensive Paleozoic collection made in the southern Appalachians by the geologist Dr. Charles Butts. This collection, numbering more than 10,000 specimens and representing the accumulation of many years of field work, is highly important for the information it contains bearing on the stratigraphy of the Appalachians. Another worthy transfer consisted of 3,500 Silurian, Devonian, and Cretaceous fossils from the Canol Project, Canada, which came from the Chief of Engineers, United States Army. The Zimm collection of about 3,000 Devonian (Oriskany) fossils from Glenrie, N. Y., came to the Museum as a purchase through the Walcott fund. The collecting work of the curator, Dr. G. Arthur Cooper, brought in much important invertebrate material from the Appalachians and Mexico and will add a fair number of types to the collection. In addition, many gifts and exchanges of invertebrate fossils were received—too numerous to list here but representing many type specimens or examples otherwise of interest and value.

The outstanding exhibition specimen received in the field of vertebrate paleontology was a composite skeleton of the large flightless pigeon *Dodo ineptus* from Mauritius, transferred from the division of birds. Skeletal remains of this extinct creature are exceedingly rare. A collection of 350 fossil sharks' teeth and a nearly complete dental plate of the extinct ray *Myliobatis* (Miocene of the Chesapeake Bay region); a molar tooth of the northern elephant, *Mammonterus primigenius*; and an avian egg found 7½ feet below the surface of Tinian Island, Marianas, are accessions to the study series deserving special mention.

Engineering and industries.—The year's outstanding accession in this department was the first experimental jet-propelled pursuit airplane built and successfully flown in the United States. Designed and constructed by the Bell Aircraft Corp., it holds the unique position of being the first propellerless airplane in the Museum's collection, as well as representing perhaps the greatest development in aeronautical engineering in the past decade.

To the automotive collections came two unique gifts—a radial 9-cylinder Diesel engine, of the type designed for and used in the United States Army M3 light tank, and an original, beautifully preserved 1902 Oldsmobile. Two accessions of note to the department's radio communications collections were a Marconi coherer, a device which formed the "heart" of wireless telegraphy before the invention of the electron tube, and an early (1911) spark transmitter, designed for wireless communication between an airplane and the ground. Another interesting communications object added was an original electric telegraph fire-alarm and street box, such as was installed on the streets of Boston in 1851.

In textiles, an outstanding accession was a historic document comprising the original indenture of Samuel Slater, dated January 8, 1783, which he brought with him from England when at the age of 20 he decided to try his fortune in America. Wartime textiles and those inspired by the war were represented in many gifts. To the collections of early homecraft textiles there were added by gifts and loans a number of noteworthy specimens of weaving, needlework, and supplementary items.

A gift of historic importance to the section of chemical industries was a series of specimens of lewisite, American mustard gas, or "blister gas," and derivatives therefrom, all prepared for exhibition. Important additions to the wood collection were 20 samples from the Russell Islands group of the Solomons, 12 from Brazil, and 63 from the Philippines. In the division of medicine the outstanding accession was the entire equipment and furnishings of an Old World apothecary shop of the period of 1750. This large collection, consisting of nearly 1,200 specimens, was gathered in Europe over a period of 40 years and is unique in completeness of original materials and in its variety.

Chief among the accessions in graphic arts was the unique gift of Charles W. Dahlgreen of 76 copper plates of his original work in etching, aquatint, and drypoint. These plates, many of which are in almost unused condition, were deposited with the division with the understanding that they are to be used to make prints, to be sold as a "Smithsonian Edition," the proceeds to compose the Charles W. Dahlgreen fund, which will be used to enlarge and improve the collections of graphic arts. The section of photography, among other valuable gifts, received a collection of rare old lenses of French, English, German, and American manufacture, and also the first portable motion-picture projector designed, patented, and made in 1912 by Dr. H. A. DeVry, often referred to as "the father of visual education."

History.—Perhaps the most outstanding addition to the historical collections was the gift of a series of 48 bronze statuettes of notable contemporary American public men, made from life by the distinguished sculptor Max Kalish. The series is entitled "The Living Hall of Washington, 1944" and is on exhibition in the costumes hall in the Arts and Industries Building. Valuable additions to the costumes collections included two gowns worn by Mrs. Herbert Hoover in the White House, two inaugural gowns worn by Mrs. Franklin D. Roosevelt, and a cape worn by the Honorable Hamilton Fish in the early nineteenth century. There was placed on special exhibition in the Natural History Building a doll dressed in the costume of Brittany which was presented to Gen. Dwight D. Eisenhower by the children of Normandy in gratitude for their liberation from the Nazis. Accessions to the military collections included an office desk and chair

used by General Eisenhower in the European war zone in 1944. The usual number of interesting numismatic items were received, including samples of recent mintages, and the philatelic collection was increased by 1,306 specimens during the year.

EXPLORATIONS AND FIELD WORK

The principal studies in the field, like those of last year, related directly or indirectly to the war and have been considerably reduced below the usual level of times of peace. The results have been valuable and have covered a variety of subjects.

In continuation of the program for the promotion of cultural relations with scientists in the other American republics in cooperation with the Department of State, Dr. E. A. Chapin, curator of insects, traveled in Chile for work in connection with entomologists and entomological collections in that country. Upon his arrival in Santiago arrangements were made by the Chilean Government for him to visit forested areas, both natural and artificial, the agricultural extension stations, and the agricultural schools in southern Chile between Santiago and the Island of Chiloé. About 5 weeks were spent on this trip, and many important contacts were made. Although the season was unfavorable, some very interesting insects were observed and collected. The last 3 weeks of Dr. Chapin's 2-month sojourn were spent in Santiago, where considerable work was done on the Chilean national collection at the museum. Arrangements were also made to render assistance to the Department of Agriculture in Chile in their white-grub work; and exchanges were arranged with certain collectors in Santiago.

In connection with this same program of cultural cooperation with the American republics, Dr. T. Dale Stewart, curator of physical anthropology, went to Mexico on March 8, returning on June 23. The primary purpose of this trip was to give training in methods of osteometry to the graduate students of the Escuela Nacional de Antropología. Owing to the recent activities of the Instituto de Antropología e Historia, of which the Escuela and Museo Nacional are part, Mexico is now one of the leading anthropological centers in this hemisphere. The subject of physical anthropology is handled by such able workers as Dr. D. F. Rubín de la Borbolla, the acting director of the Escuela, Sr. Javier Romero, curator in the Museo, Dr. Juan Comas, and Srta. Ada d'Aloja. Under them a number of young students are developing who already have had extensive field experience. In addition, Dr. Stewart was able to study a collection of skeletal remains in the Museo Nacional de Antropología collected by Dr. Eduardo Noguera earlier in the year at Xochicalco. This collection,

although small, is unusually well preserved, and contains interesting examples of tooth mutilation and cranial deformity. The teaching and research supplemented one another as the Xochicalco collection was used for demonstration purposes, particularly as regards restoration, sexing, aging, and pathological changes. Much interest in this field of research has developed as a result of this work.

A third project was concerned with work in Haiti for the Museum by Dr. Alfred Métraux, of the Institute of Social Anthropology, from September 18 to November 30. His investigations concerned anthropology and were made in cooperation with the Bureau of Ethnology of Haiti and the Scientific Society of Haiti. For a month Dr. Métraux conducted cooperative archeological investigations on Tortue Island in the north, and for another month he was in Port-au-Prince engaged in lectures and anthropological investigations. During the entire period Dr. Métraux maintained close contact with the Scientific Society for which he organized seminars for the discussion of anthropology.

In continuation of the ornithological reconnaissance of northeastern Colombia, M. A. Carriker, Jr., of Santa Marta, went into the field to complete examination of the valley separating the Sierra Nevada de Santa Marta from the Sierra Perijá. At the end of the fiscal year he had moved into the lower elevations of the Sierra Nevada where this range extends to the east toward the Guajira desert. Excellent results were reported in additional specimens for our rich collections from this area. This work is financed by the income of the W. L. Abbott fund.

A few local collections have been made by Dr. Leonard P. Schultz and Dr. Robert R. Miller, curator and associate curator of fishes, respectively, who secured fossils at Scientists Cliffs, on Chesapeake Bay, and fishes from various creeks in the State of Maryland. Several of the insect specialists have made extensive, largely local, collections within their own groups, some 3,000 specimens being added to the national collections through these efforts, a number being forms new to the collections, especially in the case of coleopterous larvae and the Aleyrodidae. Most of the aleyrodid material was obtained by Miss Louise Russell from preserved plant material at the National Herbarium and in the Herbarium of the New York Botanical Gardens.

Dr. G. Arthur Cooper, curator of invertebrate paleontology, in company with Dr. Byron N. Cooper, of the Virginia Geological Survey, carried on further investigations in the complicated geology and paleontology of the nearby Appalachian Valley, during two brief field trips. The first, in June 1944, covered parts of this area as far north as southern Pennsylvania and south to Staunton, Va., to study facies changes in the Ordovician limestone (Chambersburg formation) from its type area near Chambersburg, Pa., to a point in the vicinity of

Staunton. About 2 weeks were spent in the study, which resulted in interesting information and good collections.

A second trip extended these studies through the Ordovician rocks of southern Virginia and Tennessee. On this trip the two men were accompanied by Dr. Raymond S. Edmundson, also of the Virginia Geological Survey. The party began work about the middle of October near Athens, Tenn., and visited type sections of Ordovician formations in Virginia and Tennessee to see if the Tennessee formations could be recognized in southern Virginia. The party worked from Athens north to Knoxville, then went to Clinton, Tenn., and worked from there to Cumberland Gap in northern Tennessee. From here they traveled for a short distance along the Cumberland Front and on to Natural Bridge, and then to Harrisonburg to tie the studies into the work of the early part of the summer. The work was completed in early November.

At the end of January 1944 Dr. Alexander Wetmore, with Dr. J. P. E. Morrison, assistant curator of mollusks, as assistant, went to Panamá to inaugurate some biological investigations for the War Department which continued into the fiscal year 1945. Dr. Wetmore returned late in March, leaving Dr. Morrison to continue the work until October. As one result the Museum now has extensive collections of birds, mollusks, and reptiles as well as valuable lots in other fields from some islands of the Archipiélago de las Pérlas that have not been well known previously.

MISCELLANEOUS

Visitors.—An increase of 197,951 visitors to the Museum buildings was recorded over the previous year, the totals being 1,730,716 for 1945 and 1,532,765 for 1944. August 1944 was the month of largest attendance, with 183,394 visitors; July, the second largest, with 177,065. Records for the four buildings show the following numbers of visitors: Smithsonian Building, 342,762; Arts and Industries Building, 674,920; Natural History Building, 531,712; Aircraft Building, 181,322.

Publications.—Twenty Museum publications were issued during the year—1 Bulletin (pt. 3 of Checklist of the Coleopterous Insects of Mexico, Central America, the West Indies, and South America, by Dr. Richard E. Blackwelder), 1 Contribution from the National Herbarium, and 18 Proceedings papers. A complete list of these publications is given in the report on publications, appendix 10.

Special exhibits.—Twelve special exhibits were held during the year under the auspices of various educational, scientific, recreational, and governmental groups. In addition, the department of engineering and industries arranged 24 special displays—12 in graphic arts and 12 in photography.

CHANGES IN ORGANIZATION AND STAFF

Changes during the year in the organization and staff included the advancement of John E. Graf from Associate Director, United States National Museum, to the position of Assistant Secretary of the Smithsonian Institution on April 1, 1945.

The department of anthropology lost, through retirement, Richard G. Paine, scientific aid in the division of archeology, on February 28, 1945, and to this vacancy Joseph R. Caldwell was appointed on April 9, 1945. Robert A. Elder, Jr., was appointed assistant curator in the division of ethnology on May 16, 1945.

On the staff of the department of biology, an honorary appointment was conferred on Maj. W. L. Jellison, A. S. F., U. S. A., as collaborator in the division of insects, on August 2, 1944. Other additions were the appointment of Dr. Raymond M. Gilmore, associate curator in the division of mammals, on September 2, 1944; Mrs. Marie P. Fish, scientific aid in the division of fishes, on December 4, 1944; William E. Hoffmann, associate curator in the division of insects, on August 18, 1944, and Mrs. Mildred S. Wilson, assistant curator (aquatic biology) in the division of marine invertebrates, on August 21, 1944. Three employees left the service; one, James O. Maloney, aid in the division of marine invertebrates, resigned effective April 15, 1945, and through retirement, John A. Mirguet, osteologist, on October 31, 1944, and Earl D. Reid, scientific aid, division of fishes, on February 28, 1945.

Through the retirement of Nicholas W. Dorsey, accountant and auditor, on May 31, 1945, after long service to the Museum, Thomas F. Clark was advanced to fill the vacancy on June 16, 1945. Mrs. Anna W. Murray was appointed assistant accountant and auditor on April 30, 1945, to fill the position made vacant by the transfer of Mrs. Florence L. Weirich to the Department of Agriculture on April 8, 1945.

Other changes in the administrative staff during the year were the resignations of Mrs. Margaret M. Pflieger, assistant purchasing officer, on February 28, 1945, and Mrs. Margaret L. Vinton, personnel assistant, on January 4, 1945. These vacancies were filled by the promotion of Armstead D. Hilliard and Gertrude R. R. Bogdan, respectively, on March 1, 1945.

On the staff of maintenance and operation, William Crossingham, mechanic (foreman of paint shop), retired on September 30, 1944, and on October 9, 1944, Axel J. Anderson succeeded him in charge of the paint shop.

The following, upon completion of military duty, returned during the year to their positions in the Museum: Reuben W. Gore, February 14, 1945; Robert E. Kirk, May 16, 1945; and John B. J. Peck, January

12, 1945. On February 26, 1945, Oliver N. Armstead was furloughed for military duty.

Through the operation of the retirement act, 11 employees were retired, as follows: For age—Mrs. Marie Arm, forewoman of charwomen, on August 31, 1944, with 32 years 3 months of service; Nicholas W. Dorsey, accountant and auditor, on May 31, 1945, with 50 years 3 months of service; Richard G. Paine, scientific aid, on February 28, 1945, with 44 years 4 months of service. For optional retirement—William Crossingham, mechanic (foreman of paint shop), on September 30, 1944, with 47 years of service; Harry Kaiser, mechanic (painter), on June 30, 1945, with 35 years 10 months of service; John A. Mirguet, osteologist, on October 31, 1944, with 35 years 4 months of service; Earl D. Reid, scientific aid, on February 23, 1945, with 34 years 8 months of service; Clarence T. Taylor, guard, on June 30, 1945, with 25 years 7 months of service; and Mrs. Eleanor C. White, scientific aid, on November 30, 1944, with 25 years 8 months of service. For disability—James W. Burns, guard, on May 31, 1945, with 9 years 11 months of service, and Winfield S. Dean, mechanic, on November 1, 1944, with 18 years 7 months of service.

Through death the Museum lost during the year Louis B. Hanks, guard, on June 21, 1945, and Carter C. Wood, laborer, on April 2, 1945.

Respectfully submitted.

ALEXANDER WETMORE, *Director.*

THE SECRETARY

Smithsonian Institution

APPENDIX 2

REPORT ON THE NATIONAL GALLERY OF ART

SIR: I have the honor to submit, on behalf of the Board of Trustees of the National Gallery of Art, the eighth annual report of the Board, covering its operations for the fiscal year ended June 30, 1945. This report is made pursuant to the provisions of the act of March 24, 1937 (50 Stat. 51), as amended by the public resolution of April 13, 1939 (Pub. Res. No. 9, 76th Cong.).

ORGANIZATION AND STAFF

During the fiscal year ended June 30, 1945, the Board consisted of the Chief Justice of the United States, the Secretary of State, the Secretary of the Treasury, and the Secretary of the Smithsonian Institution, *ex officio*; and five general trustees, David K. E. Bruce, Ferdinand Lammot Belin, Duncan Phillips, Samuel H. Kress, and Chester Dale.

At its annual meeting, held on February 12, 1945, the Board elected Samuel H. Kress as President, succeeding David K. E. Bruce who resigned, and re-elected Ferdinand Lammot Belin as Vice President, to serve for the ensuing year. The executive officers continuing in office during the year were:

Huntington Cairns, Secretary-Treasurer.

David E. Finley, Director.

Harry A. McBride, Administrator.

Huntington Cairns, General Counsel.

John Walker, Chief Curator.

Macgill James, Assistant Director.

Donald D. Shepard continued to serve during the year as Adviser to the Board.

During the year Margaret D. Garrett was appointed Acting Chief of the Inter-American Office, to succeed Porter A. McCray, who resigned.

The three standing committees of the Board, provided for in the bylaws, as constituted at the annual meeting of the Board, held February 12, 1945, were:

EXECUTIVE COMMITTEE

Chief Justice of the United States, Harlan F. Stone, Chairman.

Samuel H. Kress, Vice Chairman.

Ferdinand Lammot Belin.

Secretary of the Smithsonian Institution, Dr. Alexander Wetmore.

David K. E. Bruce.

FINANCE COMMITTEE

Secretary of the Treasury, Henry Morgenthau, Jr., Chairman.

Samuel H. Kress, Vice Chairman.

Ferdinand Lamot Belin.

David K. E. Bruce.

Chester Dale.

ACQUISITIONS COMMITTEE

Samuel H. Kress, Chairman.

Ferdinand Lamot Belin, Vice Chairman.

Duncan Phillips.

Chester Dale.

David E. Finley, ex officio.

The permanent Government positions on the Gallery staff are filled from the registers of the United States Civil Service Commission, or with its approval. On June 30, 1945, the permanent Government staff of the Gallery numbered 245 employees. Since the beginning of the war 61 members of the staff, or approximately 25 percent, have entered the armed services, and during the past year 5 of these employees have obtained their discharges and have returned to the Gallery.

The operating and maintenance staffs have been reduced to a minimum, owing to the fact that the Gallery has desired to curtail expenditures and the use of manpower to the greatest possible extent during the war period. Nevertheless, owing to the intensive effort, interest, and efficiency of the employees, it has been possible to maintain a high standard of operation and maintenance of the Gallery building and grounds and protection and care of Gallery collections.

APPROPRIATIONS

For salaries and expenses for the upkeep and operation of the National Gallery of Art, the protection and care of works of art acquired by the Board, and all administrative expenses incident thereto as authorized by the act of March 24, 1937 (50 Stat. 51), as amended by the public resolution of April 13, 1939 (Pub. Res. No. 9, 76th Cong.), the Congress appropriated for the fiscal year ended June 30, 1945, the sum of \$642,600. This amount includes the regular appropriation of \$634,000 and a supplemental deficiency appropriation of \$8,600 for increases in personal services and other Gallery expenses.

From these appropriations the following expenditures and encumbrances were incurred:

EXPENDITURES AND ENCUMBRANCES

Personal services.....	\$521, 211. 91
Printing and binding.....	1, 838. 17
Supplies and equipment, etc.....	119, 425. 88
Unencumbered balance.....	124. 04
Total	642, 600. 00

In addition to the above-mentioned appropriations, the Gallery received the sum of \$35,000 from the Department of State to cover expenses during the fiscal year of the Inter-American Office of the Gallery for the promotion of art activities between the United States and the Latin American republics.

ATTENDANCE

During the year 1945 the Gallery enjoyed the largest annual attendance since the building was opened to the public in 1941, the number of visitors being 2,078,739, as compared with 2,060,071 in the fiscal year 1944, or an increase of 18,668. This is an average daily attendance of 5,711 visitors, showing the continuing popularity of the Gallery. The greatest number of visitors on any one day was 25,023, on Sunday, September 10, 1944.

Men and women in the armed services are visiting the Gallery in increasing numbers, accounting for approximately 35 percent of the total attendance. For relaxation they make constant use of the Servicemen's Room, where writing and reading materials are furnished them.

The Sunday night openings, together with the Sunday evening concerts offered free of charge, continued throughout the year and contributed to the public's interest. Special exhibitions of contemporary art held during the year, especially art produced by members of the armed services, have been unusually well attended.

PUBLICATIONS

The most ambitious project of the Publications Fund of the Gallery since its organization was the publication of the book "Masterpieces of Painting from the National Gallery of Art" in October 1944. The book contains 85 color reproductions of paintings in the Gallery collections, each matched with an interpretive passage from the world's literature, and was edited by Huntington Cairns and John Walker, of the Gallery staff. The public demand for this book has been so great that a second edition is now being printed.

The Information Rooms of the Gallery continued the policy of furnishing moderately priced color reproductions of fine quality, and increased the variety of postcards, portfolios, and illustrated catalogs available to the public. A new edition of the General Information booklet, which is of great assistance to visitors and may be obtained without charge upon request at the Information Rooms, was issued during the year.

Publishers of large collotype reproductions of paintings from the Gallery collections have been gradually adding to their lists, and the

8 new reproductions completed during the year make a total of 23 large reproductions offered for sale in the Information Rooms.

CONSTRUCTION OF NEW GALLERIES

In keeping with recommendations of the committee on the building and a resolution of the Board of Trustees, it was decided to proceed with the finishing of six new galleries, in order to make available additional exhibition space now required.

Accordingly, a contract was entered into for the completion, with funds donated for the purpose, of galleries numbered 24, 25, and 26 in the west end of the building, in which will be exhibited recent acquisitions of paintings and sculpture of Italian schools, and galleries numbered 53, 54, and 55, in the east end of the building, for exhibiting paintings of French and British schools. These galleries will be furnished in a manner similar to adjacent gallery rooms, and it is contemplated that the work will be completed in the autumn of 1945.

RETURN OF WORKS OF ART FROM PROTECTIVE STORAGE IN BILTMORE, N. C.

It was decided by the Board of Trustees that the works of art in protective storage at Biltmore, N. C., during the period of danger of air raids, should be returned to the National Gallery of Art, and this return was effected on October 17-18, 1944.

The works of art were brought back to Washington by motor van, under police protection, through the States of North Carolina and Virginia, and the District of Columbia, and the trip was accomplished without damage to any of the works of art. The storage rooms at Biltmore House were closed, and the sum of \$10,199.85, which was the unexpended balance in the working fund furnished to the National Gallery of Art for maintenance of the evacuation center, was returned to the Public Buildings Administration.

In this same connection, it may be noted that the air raid protective measures in effect in the Gallery building have been discontinued.

ACQUISITIONS

GIFTS OF PAINTINGS AND SCULPTURE

During the year the Board of Trustees received from Samuel H. Kress and the Samuel H. Kress Foundation 80 important Italian, French, and Dutch paintings and 26 pieces of sculpture, to be added to the other gifts of paintings and sculpture now in the Gallery.

On September 25, 1944, the Board of Trustees accepted the portrait of "Chief Justice Harlan F. Stone" by Augustus Vincent Tack from Duncan Phillips, to be placed in the Board Room. On the same date

the Board of Trustees accepted the portrait of "Joseph Dugan" by Thomas Sully from Herbert L. Pratt. The Board of Trustees, on November 17, 1944, accepted the painting "Both Members of This Club" by George Bellows from Chester Dale, and on January 2, 1945, the Board accepted two portraits, "Mrs. Chester Dale" and "Chester Dale," by George Bellows, from Chester Dale, the latter to be installed in the Founder's Room. A copy of a painting entitled "Madonna and Child with the Magdalen and Saint Jerome" by Matthew Pratt, after Correggio, was accepted on February 12, 1945, by the Board from Clarence Van Dyke Tiers for the study collection, and on May 21, 1945, the Board accepted from Mrs. Huttleston Rogers the painting "The Lackawanna Valley" by George Inness.

GIFTS OF PRINTS AND DRAWINGS

The Board of Trustees on September 25, 1944, November 14, 1944, November 18, 1944, May 2, 1945, and June 22, 1945, accepted as gifts a total of 1,740 prints and drawings from Lessing J. Rosenwald, to be added to his former gifts of prints and drawings. Also on September 25, 1944, the Board accepted the original drawing "Shadows" by Kerr Eby from Kerr Eby, and the drawing "Prairie Titlark" by John James Audubon from Miss Martha Hogan. On November 16, 1944, the Board accepted nine sheets of drawings by George Cruikshank from Dr. Clements C. Fry, two drawings, "Seated Figure" and "Standing Figure" by Lancret, and "Sheet of Sketches" by Lancret, from Myron A. Hofer, a mezzotint of Reynold's "Lady Betty Compton" by Valentine Green from David Keppel, and two drawings, "Seth Hastings" and "James Campbell," by Saint Memin, from Herbert L. Pratt, Jr. On May 14, 1945, the Board accepted an engraving by E. Mandel after Raphael's "The Small Cowper Madonna" from David E. Finley, and an engraving of Raphael's "The Alba Madonna" by B. Desnoyers from David Keppel. On June 22, 1945, the Board accepted two drawings, "Danseuse vu de Dos et Trois Etudes de Pieds" by Degas and "Deux Avocats" by Daumier, and one print, "Le Stryge" by Meryon, from Myron A. Hofer.

SALE OR EXCHANGE OF WORKS OF ART

The Board of Trustees accepted the offer of Samuel H. Kress and the Samuel H. Kress Foundation to exchange the sculpture "Madonna and Child" by Andrea Sansovino for the painting entitled "A Pagan Rite" by Giovanni Bellini; and the sculpture "Profile of a Woman" by Pierino da Vinci for the painting "Portrait of a Man" by Nicolas de Largilliere. The Board of Trustees also accepted the offer of Lessing J. Rosenwald to exchange an engraving by Schongauer entitled "The Eagle of Saint John, the Evangelist," and an etching by

Hirschvogel entitled "Landscape with Buildings," for a similar engraving and a similar etching, now included in the Rosenwald collection at the National Gallery of Art, and bearing the same titles and by the same artists.

LOAN OF WORKS OF ART TO THE GALLERY

During the year the following works of art were received on loan:

<i>Particulars</i>	<i>Artist</i>
From Chester Dale, New York, N. Y.:	
Le Chevalier Louis Euseba de Montour-----	Carle Van Loo.
The Sicard David Children-----	Thomas Sully.
From Mrs. Jean de Bekessy, Washington, D. C.:	
The Duchess of Parma and Her Daughter	
Isabel-----	Jean Marc Nattier.
From Myron A. Hofer, Washington, D. C.:	
Nine prints and drawings-----	{ Gainsborough. Guys. Reynolds. Whistler.
From David Keppel, Washington, D. C.:	
Sketch of Anne-----	George Bellows.
The Dream-----	Robert Nantueil.
From Robert Rosenwald, Jenkintown, Pa.:	
Aristide Bruant-----	Toulouse-Lautrec.
Anne-----	George Bellows.
Lion d'Atlas-----	Eugene Delacroix.
From Arnold Knauth, New York, N. Y.:	
Colonel Epes Sargent-----	John Singleton Copley.
From Stanley J. Mortimer, Jr., New York, N. Y.:	
Portrait bust of a member of the Order of	
San Iago-----	After the manner of Leone Leoni.
Portrait bust of a man-----	Attributed to Tullio Lom- bardi.
Madonna and Child-----	Attributed to Ghiberti.
From Duncan Phillips, Washington, D. C.:	
Macbeth and the Witches-----	A. P. Rider.
From Lieutenant Frederick R. Pratt, Washing- ton, D. C.:	
George Washington-----	Gilbert Stuart.
Battle between the <i>United States</i> and the <i>Macedonia</i> -----	Thomas Birch.
Battle between the <i>Wasp</i> and the <i>Frolic</i> -----	Thomas Birch.
From Lessing J. Rosenwald, Jenkintown, Pa.:	
Ecce Homo III (Christ Presented to the People)-----	Rembrandt.
Ecce Homo VII (Christ Presented to the People)-----	Rembrandt.
From museums and private collectors in Europe:	
154 paintings of the French school of the late eighteenth and nineteenth centuries and	
101 French drawings.	

LOAN OF WORKS OF ART BY THE GALLERY

During the fiscal year 1945, the Gallery loaned the following works of art for exhibition purposes:

<i>Particulars</i>	<i>Artist</i>
To the Art Institute of Chicago, Chicago, Ill.:	
Mrs. Richard Yates-----	Gilbert Stuart.
To the Virginia Museum of Fine Arts, Richmond, Va.:	
Nineteen paintings-----	Gilbert Stuart.
To the Century Association, New York, N. Y.:	
Chief Justice Charles Evans Hughes-----	Augustus Vincent Tack.
Chief Justice Harlan F. Stone-----	Augustus Vincent Tack.
To the Museum of Art, Providence, R. I.:	
Mrs. Richard Yates-----	Gilbert Stuart.
To the White House, Washington, D. C.:	
George Washington-----	Rembrandt Peale.
Allies Day, May 1917-----	Childe Hassam.
To the United States Department of State—Blair Lee House, Washington, D. C.:	
Daniel Webster-----	P. A. Healy.
Seven prints from the Rosenwald collection.	

LOANED WORKS OF ART RETURNED

During the year the print "Saint Jerome beside a Pollard Willow" by Rembrandt, lent to the Gallery by W. G. Russell Allen, was returned to him.

EXHIBITIONS

The following exhibitions were held at the National Gallery of Art during the fiscal year ended June 30, 1945:

American Battle Art paintings—Revolutionary War to World War I, from museums and private collections, from July 4 to September 4, 1944.

American portraits from the Gallery's collection, from September 5 to November 13, 1944.

Paintings of Naval Medicine from the Abbott Laboratories and the United States Government, from September 10 to October 18, 1944.

Paintings and drawings of the United States Coast Guard by United States Coast Guard combat artists, from September 17 to October 18, 1944.

Wartime paintings of flyers, planes, and world-wide combat operations of the Army Air Forces, by Army Air Forces artists, from October 15 to November 10, 1944.

Nineteenth-century etchings and drawings by Legros from the collection of George Matthew Adams, from October 15 to November 12, 1944.

Eighteenth-century prints and drawings from the Widener collection, the Dr. A. W. S. Rosenbach collection, and the Mrs. Irwin Laughlin collection, from November 19, 1944, to January 14, 1945.

French drawings from the French Government, the Myron A. Hofer collection, and the Harris Whittemore collection, from November 19, 1944, to May 8, 1945.

Italian eighteenth-century prints from the Gallery's collection, from February 28 to May 21, 1945.

Religious prints and drawings from the Gallery's collection, from May 9 to June 19, 1945.

Prints and drawings from the Gallery's collection and the Myron A. Hofer collection, from May 9 to June 19, 1945.

Paintings of The War against Japan by American artists in the Pacific areas, from the Treasury Department, with the cooperation of the Army, Navy, and Marine Corps, and Life Magazine, from May 27 to June 19, 1945.

TRAVELING EXHIBITIONS

During the fiscal year ended June 30, 1945, the following drawings, water colors, and prints were placed on exhibition:

Index of American Design.—When the Index of American Design was transferred from the Metropolitan Museum of Art, New York, N. Y., where it has been on loan, it contained 16 special traveling exhibitions which had been arranged by that institution. The National Gallery of Art has subsequently added four traveling exhibitions to this number. Exhibitions from the collection have been shown at the following places during the fiscal year just ended: Worcester Art Museum; Metropolitan Museum of Art; Ohio State Museum; John Herron Art Institute; Rhode Island State College; Children's Museum, Washington, D. C.; Little Gallery, North Canton, Ohio; Kanawha County Public Library; Baltimore Museum of Art; University of New Hampshire; Pasadena Art Institute; and Union Gallery, University of Wisconsin.

Rosenwald prints.—Special exhibitions of prints from the Rosenwald collection were prepared and circulated during the past fiscal year. These exhibitions were held at Cheltenham Art Center, Elkins Park, Pa.; the Print Club, Philadelphia; Philadelphia Museum of Art; John Herron Art Institute, Indianapolis, Ind.; Philadelphia Art Alliance; Wesleyan University, Middletown, Conn.

CUSTODIANSHIP OF FRENCH EXHIBITION MATERIAL

The Board of Trustees, on February 1, 1945, relinquished its custodianship of, and transferred to the Provisional Government of the French Republic in the United States, all works of art and exhibition material sent to the United States under the auspices of the former French Government for exhibition purposes at various places in the United States, including the World's Fairs in New York, N. Y., and San Francisco, Calif.

VARIOUS GALLERY ACTIVITIES

During the period from July 1, 1944, to June 30, 1945, a total of 51 Sunday evening concerts were given in the East Garden Court of the Gallery. The concerts were free to the public and were attended by capacity audiences. The National Gallery Sinfonietta, under the direction of Richard Bales, played 11 concerts, with well-known guest artists appearing occasionally. The Gallery's second American Music Festival of works of American composers was held on four Sunday evenings in March 1945.

The Sunday night suppers for servicemen continued during the year and were enjoyed by approximately 1,700 service men and women. Funds to defray the cost of the suppers were contributed by members of the Gallery staff and by friends of the Gallery.

The film "National Gallery of Art" was made available during the year to 17 individuals and institutions.

The Inter-American Office has continued during the year to carry out the Latin-American art program of the Department of State through the exchange of exhibitions, the distribution of art materials and publications, and the assembling of information on Inter-American art activities. Major exhibitions were organized and sent to seven countries in Latin America.

With the cooperation of the Library of Congress, the Inter-American Office edited the directory to Latin-American art activities originally prepared by the Archive of Hispanic Culture, for publication in the forthcoming issue of the American Art Manual for the years 1942-45. The Inter-American Office has also compiled a list of circulating exhibitions of Latin American art in the United States, which will be available for distribution in the early autumn of 1945.

A total of 188 special permits to copy paintings in the National Gallery of Art were issued during the fiscal year 1945, and during the same period 75 special permits were issued to photograph paintings.

CURATORIAL DEPARTMENT

The curatorial work during the fiscal year consisted of installing new gifts, particularly the additional items of the Samuel H. Kress collection, and reinstallation of the evacuated works of art returned from Biltmore, N. C.; work on the new Gallery catalog and the photographic record of the Gallery collections; assisting the American Commission for the Protection and Salvage of Artistic and Historic Monuments in War Areas by providing information on damaged and looted works of art in war areas; assisting in the publication of the book "Masterpieces of Painting from the National Gallery of Art," edited by Huntington Cairns and John Walker; collaborating in the publication of the book "Drawings for Ariosto by Fragonard"; completion of a "Handbook of the Widener Collection of Decorative Arts"; completion of one catalog and three pamphlets in the series dealing with important works in the collection; and the cataloging of the Richter Photographic Archives and the Strauss collection of photographs. Seven members of the staff contributed 14 articles to periodicals, and three members of the staff lectured 13 times on six subjects.

During the year approximately 1,903 works of art were submitted to the Acquisitions Committee (including 1,740 prints from the Rosenwald collection) with recommendation regarding their acceptability

for the collection of the Gallery; 46 private collections were reviewed in connection with offers to the Gallery of gifts or loans; 128 consultations were held concerning more than 250 works of art brought to the Gallery for expert opinion; 116 written and 107 verbal replies involving research in the history of art were made to inquiries; and 8 visits were made outside the Gallery to view works of art for expert opinion.

RESTORATION AND REPAIR OF WORKS OF ART

With the authorization of the Board and the approval of the Director and Chief Curator, the necessary restoration and repair of works of art in the Gallery's collection were made by Stephen S. Pichetto, Consultant Restorer to the Gallery. All work was completed in the Restorer's studio in the Gallery with the exception of several works of art requiring attention before they could with safety be shipped to Washington, D. C., and two paintings on which the work was of such a delicate and complicated nature that it had to be done in Mr. Pichetto's New York studio.

EDUCATIONAL PROGRAM

The various programs conducted by the educational department continued to be popular. The Gallery tours of the collection attracted more than 15,000 people, and nearly 27,000 attended the two 10-minute lectures given daily on the "Picture of the Week." This latter attendance is an increase of 5,000 over the fiscal year 1944. Illustrated lectures on 57 special topics were given in the auditorium by members of the educational and curatorial departments and by guest speakers.

LIBRARY

A total of 1,035 books and 299 pamphlets and periodicals were presented to the Gallery; 9 books were purchased by the Gallery; 3,020 photographs and 45 slides were presented as gifts; 22 books, 68 pamphlets, and 357 bulletins were acquired through exchange, and 20 subscriptions to periodicals were made.

PHOTOGRAPHIC DEPARTMENT

During the year the photographic laboratory of the Gallery made 9,498 prints, 632 black and white slides, and 1,625 color slides.

OTHER GIFTS

During the year gifts of books on art and related material were made to the Gallery library by Maj. Paul Mellon, Mrs. Jesse Isidor Straus, Col. and Mrs. John Nicholas Brown, Capt. Cyrus R. Miller, the National Gallery of Canada, the Carnegie Institute, David E. Finley, Ferdinand Lamot Belin, Samuel H. Kress, and A. G. Gallo-

way. Gifts of money during the fiscal year 1945 were made by Richard Bales, Mrs. Florence Becker, Mrs. Dexter Brown, Mrs. Elizabeth Coolidge, Mrs. David E. Finley, Sr., David E. Finley, Macgill James, The A. W. Mellon Educational and Charitable Trust, Mrs. Lee Warren, and Mrs. Gertrude Clark Whittall.

AUDIT OF PRIVATE FUNDS OF THE GALLERY

An audit is being made of the private funds of the Gallery for the fiscal year ended June 30, 1945, by Price, Waterhouse & Co., public accountants, and the certificate of that company on its examination of the accounting records maintained for such funds will be submitted to the Gallery.

Respectfully submitted.

F. L. BELIN, *Acting President.*

Dr. ALEXANDER WETMORE,

Secretary, Smithsonian Institution.

APPENDIX 3

REPORT ON THE NATIONAL COLLECTION OF FINE ARTS

SIR: I have the honor to submit the following report on the activities of the National Collection of Fine Arts for the fiscal year ended June 30, 1945:

APPROPRIATIONS

For the administration of the National Collection of Fine Arts by the Smithsonian Institution, including compensation of necessary employees, purchase of books of reference and periodicals, traveling expenses, and other necessary incidental expenses, \$17,900 was allotted, of which \$5,998.45 was expended in connection with the care and maintenance of the Freer Gallery of Art, a unit of the National Collection of Fine Arts. The balance was spent for the care and upkeep of the National Collection of Fine Arts, nearly all of this sum being required for the payment of salaries, traveling expenses, purchase of books and periodicals, and necessary disbursements for the care of the collection.

THE SMITHSONIAN ART COMMISSION

The twenty-second annual meeting of the Smithsonian Art Commission was held on December 5, 1944. The annual meetings scheduled for the two preceding years were canceled owing to crowded transportation and hotel facilities.

The members met at 10:30 a. m. in the Natural History Building, where, as the advisory committee on the acceptance of works of art that had been submitted since the last meeting in 1941, the following action was taken:

ACCEPTED FOR THE NATIONAL COLLECTION OF FINE ARTS

Oil painting, "Roses," by John F. Weir, N. A. (1841-1926). Gift of Miss A. M. Hegeman.

Oil painting, "Mist in Kanab Canyon, Utah," by Thomas Moran, 1892. Bequest of Mrs. Bessie B. Croffut.

Four oil paintings: "Water Carriers," by Frank Duveneck; "Portrait Group of Mrs. Hawkins and Family," by Sir William Beechey; "Rome and the Campagna," by Richard Wilson; and "Lady and Two Children," by George Frederick Watts. Bequest of Rev. F. Ward Denys.

Oil painting, "Clearing after September Gale—Maine Coast," by Howard Russell Butler, N. A. (1856-1934). Henry Ward Ranger bequest.

Oil painting, "Return from the Farm," by Elliott Daingerfield, N. A. (1859-1932). Henry Ward Ranger bequest.

Oil painting, "Self Portrait," by Will H. Low, N. A. (1853-1932). Henry Ward Ranger bequest.

Oil painting, "New Year's Shooter," by George Luks (1867-1933). Henry Ward Ranger bequest.

Oil painting, "The Sermon," by Gari Melchers, N. A. (1860-1932). Henry Ward Ranger bequest.

Miniature, water color on ivory, "Unknown Lady," by David Boudon. Gift of Bernard H. Cone.

Miniature, water color on ivory, "Robert Oliphant," by Raphael Peale. Bequest of Mrs. Bertha E. Jaques.

Miniature, water color on ivory, "Elizabeth Oliphant" (sister of Robert), by James Peale. Bequest of Mrs. Bertha E. Jaques.

Miniature, water color on ivory, "Samuel Love, Jr., of Salisbury Plantation, Virginia," by Robert Field. Bequest of Admiral Richard Graham Davenport.

ACCEPTED FOR THE SMITHSONIAN INSTITUTION

Pastel, "Portrait of Mrs. Frank B. Noyes," by Juliet Thompson. Gift of Frank B. Noyes.

Oil painting, "Portrait of Gen. George B. McClellan," as a small child, by an unknown artist. Gift of Mrs. George B. McClellan.

Opaque water color, "A Bodhisattva, Cave 4, Bagh," by Sarkis Katchadourian. Gift of Neshan G. Shamigian.

Original plaster statue, "Alexander Agassiz," by Paul W. Bartlett. Gift of Mrs. Paul W. Bartlett.

Bronze, "Head of Christ," by Filomeno Melgarejo. Gift of Vice President Henry A. Wallace.

Two Italian cabinets. Gift of Mrs. Frank B. Noyes.

Two blue vases. Bequest of Miss Ida Howgate.

Japanese lacquer serving dish, Tokugawa period. Gift of Dr. Edwin Kirk.

Large Celadon vase and a pair of Ming vases. Gift of Milo Elson Emmerson.

ACCEPTED FOR THE NATIONAL PORTRAIT GALLERY

Oil painting, "Thomas A. Edison Listening to His First Perfected Phonograph," by Col. A. A. Anderson. Gift of Dr. Eleanor A. Campbell.

Oil painting, "Portrait of Dr. Charles Greeley Abbot," by Nicholas R. Brewer. Gift of the artist.

The members then proceeded to the offices of Dr. Wetmore, Acting Secretary of the Institution, for the further proceedings, and the meeting was called to order by the vice chairman, Prof. Frank Jewett Mather, Jr., as acting chairman.

The members present were: Prof. Frank Jewett Mather, Jr., vice chairman; Dr. Alexander Wetmore (ex officio); and Gifford Beal, David E. Finley, Paul Manship, Edward W. Redfield, and Mahonri M. Young. Ruel P. Tolman, curator of the division of graphic arts in the United States National Museum and acting director of the National Collection of Fine Arts, also attended.

The following resolutions on the deaths of Messrs. Lodge, Borie, and Keppel were submitted and adopted:

Whereas, the Smithsonian Art Commission has learned of the death on December 29, 1942, of Mr. John E. Lodge, a member of the Commission since 1921, and Chairman of the Executive Committee since 1941; therefore be it

Resolved, That the Commission desires here to record its sincere sorrow at the loss of Mr. Lodge. His wide experience and exceptional knowledge of the art of the Far East, his keen judgment of the quality of works of art, and his helpful interest in the affairs of the Commission will be sadly missed.

Resolved, That these resolutions be spread upon the records of the Commission, and that the Secretary be requested to inform the family of Mr. Lodge of this action.

Whereas, the Smithsonian Art Commission has learned of the death on May 11, 1943, of Mr. Charles L. Borie, Jr., a member of the Commission since 1926, and its Chairman since 1935; therefore be it

Resolved, That the Commission desires here to record its sincere sorrow at the passing of Mr. Borie, an eminent architect, whose productions are an enduring monument to his genius. He was ever ready with helpful advice in formulating the policies of the Smithsonian Art Commission and the National Collection of Fine Arts. His influence in the general promotion of the art interests of this country will be greatly missed.

Resolved, That these resolutions be spread upon the records of the Commission, and that the Secretary be requested to inform the family of Mr. Borie of this action.

Whereas, the Smithsonian Art Commission has learned of the death on September 8, 1943, of Dr. Frederick P. Keppel, a member of the Commission since 1932; therefore be it

Resolved, That the Commission desires here to record its sincere sorrow at the passing of Dr. Keppel, who, as the head of the Carnegie Foundation of New York, has exercised a profound influence in the promotion of art in the United States, and whose broad outlook and keen judgment have been of great value to the Smithsonian Art Commission. His wisdom and his genial personality will long be missed.

Resolved, That these resolutions be spread upon the records of the Commission, and that the Secretary be requested to inform the family of Dr. Keppel of this action.

The Commission recommended to the Board of Regents the name of Archibald G. Wenley to succeed Mr. Lodge, Robert Woods Bliss to succeed Dr. Keppel, and George Hewitt Myers to succeed Mr. Borie.

The following officers were elected for the ensuing year: Paul Manship, chairman; Frank Jewett Mather, Jr., vice chairman; and Dr. Alexander Wetmore, secretary.

The Commission recommended to the Board of Regents the reelection, for the usual 4-year period, of the following members whose terms expired on the dates stated: (1942) Herbert Adams, Gifford Beal, Gilmore D. Clarke; (1943) Louis Ayres, James E. Fraser, George Harold Edgell, Frank Jewett Mather, Jr.; (1944) David E. Finley, Edward W. Redfield, Paul Manship.

The following were elected members of the executive committee for the ensuing year: David E. Finley (chairman), Herbert Adams, and Gilmore D. Clarke. Paul Manship, as chairman of the Commission, and Dr. Alexander Wetmore, as secretary of the Commission, are ex officio members of the executive committee.

THE CATHERINE WALDEN MYER FUND

Seven miniatures, water color on ivory, were acquired from the fund established through the bequest of the late Catherine Walden Myer, as follows:

46. "Mr. Bennett of Revere Street, Boston, Mass.," by Henry Williams (1787-1830); from Sherman Riley, New Haven, Conn.

47. "William Mather Smith," by Archibald Robertson (1765-1835); from Mrs. Dora Lee Curtis, Arlington, Va.

48. "Mrs. William Mather Smith (nee Helen Livingston)," by an unknown artist; from Mrs. Dora Lee Curtis, Arlington, Va.

49. "Unknown Lady," by Alfred T. Agate (1812-1846); from Miss Elizabeth A. DuHamel, Washington, D. C.

50. "Mrs. Thomas Wilson," by Walter Robertson (before 1765-1802); from Mrs. Dora Lee Curtis, Arlington, Va.

51. "John Church Hamilton," (?) by Alfred T. Agate (1812-1846); from Miss Elizabeth A. DuHamel, Washington, D. C.

52. "Dr. John Binsse," (?) by Louis Binsse de St. Victor (?); from Harry Lorin Binsse, New York City.

DEPOSITS

Two plaster life masks, "Capt. Charles Francis Hall (1821-1871)," by Clark Mills (1810-1883), and "Joseph Francis (1801-1893)," by Theodore A. Mills (1839-1916), were deposited by the United States National Museum (division of ethnology).

LOANS ACCEPTED

A silver tankard was lent by Ensign Edward Shippen, U. S. N. R., through his father, Dr. L. P. Shippen, on December 13, 1944.

An oil painting, "The Nativity," by an unknown artist, was lent by St. Paul's Church, Washington, D. C., on January 25, 1945.

LOANS TO OTHER MUSEUMS AND ORGANIZATIONS

An oil painting, "Portrait of George Washington Carver," by Betsy Graves Reyneau, was lent to the Harmon Foundation, Inc., on September 21, 1944, to be included in an exhibit of portraits of leading Negro citizens shown at the Detroit Institute of Arts from October 10 through October 22, and to continue on tour in different parts of the country.

An oil painting, "Thomas A. Edison Listening to His First Perfected Phonograph," by Col. A. A. Anderson, was lent to the Mint Museum of Art, Charlotte, N. C., on September 25, 1944. (Returned November 10, 1944.)

A framed oil sketch, "Westward the Course of Empire Takes Its Way," by Emanuel Leutze, was lent to the Detroit Institute of Arts to be included in their exhibition, "The World of the Romantic Art-

ist," December 29, 1944, to January 28, 1945. (Returned February 6, 1945.)

A plaster bust of George Washington, by Houdon, was lent to the Field Photographic Branch, Office of Strategic Services, Department of Agriculture, for photographic purposes, on January 2, 1945. (Returned January 2, 1945.)

Three water colors by Walter Paris, entitled "In Monument Park, Colorado," "Landscape," and "Florida Village," and one photograph of the artist, were lent to the Lyman Allyn Museum, New London, Conn., to be included in its thirteenth anniversary exhibition, "Men of the Tile Club," March 11 through April 23, 1945. (Returned April 28, 1945.)

Five oil paintings, "Lower Ausable Pond," by Homer D. Martin; "La Vachere," by Theodore Robinson; "Moonlight," by Albert P. Ryder; "September Afternoon," by George Inness; and "At Nature's Mirror," by Ralph A. Blakelock, were lent to Howard University, Washington, D. C., to be included in the Festival of Fine Arts, May 3 through June 14, 1945. (Returned June 15, 1945.)

Two oil paintings, "Fired On," by Frederic Remington, and "Indian Summer Day," by Max Weyl, were lent to The White House June 7, 1945, the former to be hung in the Executive Office, the latter in President Truman's study, second floor.

An oil painting, "Portrait of Andrew Jackson," by R. E. W. Earle, was lent to The Baltimore Museum of Art, Baltimore, Md., June 11, 1945, to be included in their Andrew Jackson Exhibition, June 15 to July 15, 1945.

WITHDRAWALS BY OWNERS

Three original bronzes, by Antoine Louis Barye, entitled "Panther Surprising Civet Cat," "Stork on Tortoise," and "Seated Hare," lent by Leonard C. Gunnell, September 25, 1934, were withdrawn by Mrs. Gunnell on October 10, 1944.

THE NATIONAL COLLECTION OF FINE ARTS REFERENCE LIBRARY

A total of 407 publications (255 volumes and 152 pamphlets) were accessioned during the year. Of this number, 122 volumes and 46 pamphlets were added by purchase, and 54 volumes of periodicals were bound. The other accessions were publications received by exchange, gift, or transfer. The Parke-Bernet auction catalogs (priced) accounted for 35 volumes and 42 pamphlets among the purchases.

SPECIAL EXHIBITIONS

The following exhibitions were held:

July through August, 1944.—A selection of 57 oil paintings and 1 bronze, from the William T. Evans collection of American paintings.

October 5 through 29, 1944.—Exhibition of 96 portraits, by Enit Kaufman, called "The American Century."

November 3 through 26, 1944.—The Seventh Metropolitan State Art Contest, held under the auspices of the D. C. Chapter, American Artists' Professional League, assisted by the Entre Nous Club. There were 215 exhibits, consisting of paintings, sculpture, prints, and metalcraft, by 121 artists.

December 14, 1944, through January 14, 1945.—Exhibition of 78 miniatures by 45 artists, by The Pennsylvania Society of Miniature Painters. Reprint of catalog was published by the National Collection of Fine Arts.

January 4 through 28, 1945.—Exhibition of 135 water colors of Latin America, by Carl Folke Sahlin, Art Director of the Pan American League of Miami, was sponsored by the Pan American Union. A catalog was published by the Pan American Union.

February 2 through 25, 1945.—Exhibition of 66 paintings by modern Cuban painters, was sponsored by the Cuban Ambassador and the Pan American Union. A catalog was published by the Pan American Union.

March 4 through April 1, 1945.—Exhibition of 89 paintings and 6 pieces of sculpture by members of the Society of Washington Artists. A catalog was published by the Society.

April 10 through 30, 1945.—Exhibition of the 82 drawings presented to the United States by the French Republic in 1915.

PUBLICATIONS

TOLMAN, R. P. Report on the National Collection of Fine Arts for the year ended June 30, 1944. Appendix 3, Report of the Secretary of the Smithsonian Institution for the year ended June 30, 1944, pp. 39-43.

WENLEY, A. G. Report on the Freer Gallery of Art for the year ended June 30, 1944. Appendix 4, Report of the Secretary of the Smithsonian Institution for the year ended June 30, 1944, pp. 44-50.

Respectfully submitted.

R. P. TOLMAN, *Acting Director.*

Dr. A. WETMORE,

Secretary, Smithsonian Institution.

APPENDIX 4

REPORT ON THE FREER GALLERY OF ART

SIR: I have the honor to submit the twenty-fifth annual report on the Freer Gallery of Art for the year ended June 30, 1945:

THE COLLECTIONS

Additions to the collections by purchase are as follows:

BOOKBINDING

- 45.15. Egypto-Arabic, 14th century. Two covers with a flap. Brown leather with blind and gold tooling, on pasteboard. 0.371 x 0.275 (single cover).

BRONZE

- 44.57. Chinese, Chou dynasty, 4th-3d century B. C. Hook, with hinged handle. Decoration in relief and incised to receive inlay, traces of which remain. Olive-green patina. 0.223 x 0.098 over all.
- 45.30. Chinese, Sui dynasty, dated in correspondence with A. D. 609. Buddhist ex-voto: The Buddhas Gautama and Prabūtaratna. Surface gilded; areas of green patina and earthy incrustations. Dedicatory inscription, dated. 0.218 x 0.141 x 0.055.
- 45.31. Chinese, period of the Six Dynasties. Buddhist statuette: Bhaiṣajyagura (Yao-shih-fo). Surface gilded; green and reddish patina on worn areas. 0.127 (height).

CALLIGRAPHY

- 45.16. Arabic (Egypt?) 8th century. Parchment leaf from a *Qur'ān*. Text in black *kūfī* script set against a washed-out blue background. An illuminated band between two *sūras* on the reverse. 0.283 x 0.398.
- 45.17. East Persia, 10th century. Parchment leaf from a *Qur'ān*. Text in black *naskhī* script, with red vowel-marks. 0.204 x 0.302.
- 45.18. Arabic, 14th century. Fragmentary paper page from a *Qur'ān*, with a black *thulth*, text, and the word *Allāh* in gold. 0.178 x 0.361.
- 45.19- Arabic 8th-9th century. Two parchment leaves from a *Qur'ān*. Text
- 45.20. in black *kūfī* script with red vowel-marks; a *sūra* heading in gold. 45.19, 0.194 x 0.257; 45.20, 0.194 x 0.258.

CERAMICS

- 44.47. Chinese, Sung dynasty. Ying-ch'ing ware. Bowl with slightly everted lip and slightly concave foot. Body of white porcelain, covered with a pale, transparent blue glaze filled with minute bubbles. Decoration inside incised in the body; principally comb marks. 0.070 x 0.175.
- 45.1. Chinese, Ming dynasty. Potiche with short, straight neck sloping slightly inward. Body of hard, white clay, glazed in white, deep blue, turquoise blue, aubergine and brownish yellow in local areas outlined with slip edges in relief. 0.305 x 0.345.

- 45.2. Chinese, Ch'ing dynasty. Ch'ien Lung period (A. D. 1736-1796). Vase, ovoid, with low, spreading foot and flaring lip. Body of fine-grained, hard, white clay, covered with a high-fired, pale buff glaze. The decoration in *famille rose* enamels, gold and iron red over glaze. Six-character mark in gold seal characters under the base. 0.203×0.096 .
- 45.3. Chinese, Ch'ing dynasty. Ch'ien Lung period (A. D. 1736-1796). Vase, with wide shoulder and short neck. The body is of fine-grained, hard, white clay, with a pale gray, crackled glaze, coated on the outside with transparent green enamel. 0.151×0.084 .
- 45.5. Chinese, Ch'ing dynasty. Yung-ch'eng period (A. D. 1723-1736). Bottle-shaped vase; two handles on the neck. The body is of thin, white porcelain with a transparent glaze. The outside, except for the handles and foot, is coated with pink enamel, delicately painted in *famille rose* enamels with chrysanthemums, fruit, and butterflies. Four-character mark on the foot. 0.122×0.075 .
- 45.10. Chinese, 11th-12th century. Sung dynasty. Tz'ü-chou type. A large jar, with a wide mouth and two strap handles; bold foot ring. The body is of buff-colored, porcelainous stoneware. The shoulder and strap-handles are covered with a delicate, applied ribbing under a lustrous brown glaze having a minute gray speckling; the lower body with a shiny brown glaze roughened by adhesions. Possibly from Ch'ing-ho hsien. 0.286×0.276 (diameter).
- 44.49. Persian, 11th century. So-called Aghkand ware. Bowl with a narrow flat rim and low ring foot. Body of fine-grained, fairly hard, reddish-buff earthenware. The decoration, a design of a cock in scrolls, is incised in the white covering slip and colored green, yellow, and brown in local areas under a transparent glaze. 0.098×0.276 (diameter). (Illustrated.)
- 45.8. Persian, 13th century. Rayy. Bowl, standing on a low basal ring. The body is of soft, grayish clay covered with a cream-white glaze upon which a figural decoration is painted in polychrome, in so-called *minai* technique. 0.085×0.203 .

MANUSCRIPT

- 44.48. Persian, 16th century (A. D. 1524), Šafavid period. Herāt. Anthology, containing selections from the works of Jalal ad-Dīn Rumī, Nizāmī, Sa'dī, and Sanā'ī, bound in gold stamped and tooled leather. *Nasta'liq* script, written by the calligraphers Shaikh Mahmūd, Mir 'Alī Husainī, Sultān Muhammad Nūr (attr.), Muhammad Qāsim b. Shādi-Shāh, and Sultān Muhammad Khandān. Three colophons. Frontispiece by Bīzhād (see Painting, 44.48A). $0.250 \times 0.170 \times 0.022$.

NEAR EASTERN METALWORK

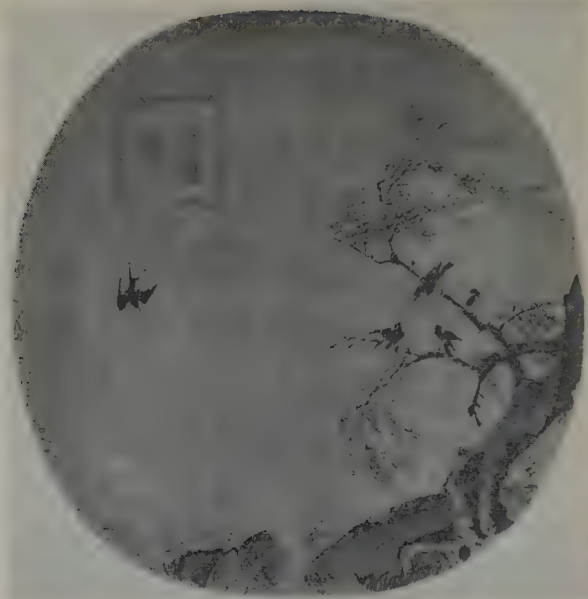
- 45.13. Persian, 6th-8th century. Sāsānian type. A bronze ewer with a pear-shaped body on a high foot; slender handle terminating in stylized antelope heads. Dark green, glossy patina with areas of red. A small repair on one side. 0.437×0.165 .
- 45.14. Veneto-Islamic, middle of the 16th century. Waterbucket with bail handle (*safl*). The outer surface of the body and the handle and a border along the inside upper edge are decorated with engraving and silver inlay. The inside is engraved and gilded. 0.322 (with handle raised); 0.197 (with handle down); 0.300 (diameter). (Illustrated.)



13. 11



44. 49



44.51



45.11

RECENT ADDITIONS TO THE COLLECTION OF THE FREER GALLERY OF ART

- 45.6. Persian, 17th century (A. D. 1683-1684). A brass astrolabe: a northern instrument fitted with a shackle for suspension equipped with a cord; a rete or *'ankabūt*, four six-partite tablets, an alidade, a pin, and a bolt. Surface ornament chased and engraved. Dated and signed by the maker, Ustad Muhammad Zamān. 0.176 x 0.129 (diameter).

PAINTING

- 44.51. Chinese, Sung dynasty. By Mao I, fl. ca. A. D. 1165. Swallows and a willow tree: a fan painting in ink on silk. Signature and two seals. 0.250 x 0.247 (diameters). (Illustrated.)
- 44.52. Chinese, Sung dynasty, 10th century. Mountain landscape: an album painting in color and ink on silk. One seal; two fragments of seals. 0.275 x 0.220.
- 44.53. Chinese, Sung dynasty, 12th century. Style of Li T'ang. Winter scene; with a man on a water buffalo carrying a ring-necked pheasant; willow, bamboo, and ilex (?). An album painting in color and ink on silk. Two half seals. 0.235 x 0.245.
- 44.50. Chinese, Yüan dynasty. Attributed to Chao Mêng-fu (A. D. 1254-1322). Three horses. Ink and slight color on silk. 0.267 x 0.219.
- 45.32. Chinese, Yüan dynasty, dated in correspondence with A. D. 1347. By Chao Yung. A horse and a groom in a red coat. A scroll painting in color and ink on paper. Signature and seal plus 25 seals and one inscription. 0.317 x 0.735.
- 45.27. Indian, Mughal, second half of the 16th century. School of Akbar. The emperor Bābur receiving the capitulation of Kābul in 910 H (A. D. 1510). "Work of Mahesh. Portraits by Basawan" (contemporary attribution). Painted in colors and gold on paper. Text in *nasta'liq* script. 0.334 x 0.202.
- 45.28. Indian, Mughal, second half of the 16th century. School of Akbar. The abduction of a princess by sea. Painted in colors, gold and silver (oxidized) on paper. A small area of text in *nasta'liq* script. 0.174 x 0.119.
- 45.9. Indian, Mughal, 17th century (ca. A. D. 1620). School of Jahāngīr. A political allegory symbolizing the peace of the world. It represents the two great rulers, Jahāngīr of India and Shāh 'Abbās of Persia, standing in mutual embrace upon the forms of a lion and a lamb crouched upon a terrestrial globe, and surrounded by a golden nimbus. Painted in colors and gold on paper as an album picture. Inscriptions. 0.238 x 0.153.
- 45.9A. The above picture is mounted within a floral border, painted in colors on a gold ground. Signed and dated: Muhammad Ṣādiq 1160 H (A. D. 1747).
- 45.29. Indian, Mughal, early 17th century. School of Jahāngīr. The world of animals. A wash drawing in pale tints. 0.234 x 0.117. Persian, early 14th century. Mongol (Il-Khān) period. Two leaves from a *Manāfi 'al-Hayawān*, with a text written in black and red *naskhī* script; one title in blue angular *kūfī* script, outlined in red. Paintings in color and gold.
- 44.54. Two owls in a tree. Paper: 0.242 x 0.199. Painting: 0.117 x 0.078.
- 44.55. Two doves in a rocky landscape. Paper: 0.262 x 0.207. Painting: 0.086 x 0.019.

- 44.56. Persian, middle 14th century. Mongol (Īl-Khān) period. Leaf from a *Shāhnāma*: Rustam slays Ashkabūs and his horse. Color and gold. Text in black *naskhī* script; title (*verso*) in red *naskhī*. Paper: 0.290 x 0.202. Painting: 0.083 x 0.152. Persian, first half of the 14th century. Mongol (Īl-Khān) period. Six miniatures from a *Shāhnāma*, painted in opaque color and gold. The paintings, minute in size and exquisitely executed, are as follows:
- 45.21. Khusraw Parwiz greeted by an old astrologer before his hermitage. 0.059 x 0.120.
- 45.22. The death of the Simurgh. 0.043 x 0.120.
- 45.23. The div Akwan about to throw the sleeping Rustam into the sea. 0.058 x 0.120.
- 45.24. Rustam encamped within sight of the hosts of Turan. 0.068 x 0.120.
- 45.25. Siyawush, while hunting with Afrasiyab, cleaves an onager in two. 0.048 x 0.120.
- 45.26. Piran stays the execution of Bizhan at the foot of the gibbet. 0.048 x 0.120.
- 45.7. Persian, Mongol (Inju) period (A. D. 1341). Shīrāz school. Illustration from a *Shāhnāma*: the hero Rustam rolling away the great boulder from the mouth of the pit where Bizhan is imprisoned. Color and slight gold; red background above ground; black background in the pit. Paper leaf: 0.352 x 0.301. Painting: 0.148 x 0.238.
- 44.48A. Persian, 15th-16th century. Herāt school. By Bīhzād. An old man and a youth in a mountain landscape: a circular composition (*shamsa*) within an illuminated border, mounted as a frontispiece to the *Anthology*, 44.48. Color, gold and silver (oxidized); surface slightly worn. Signature and inscription. 0.082 (diameter).

SCULPTURE

- 44.46. Chinese, T'ang dynasty, 8th-9th century. Image of a seated Buddha, molded in dry lacquer. Traces of color on the robe and of gilt on the flesh parts. Hands and long ear-lobes broken off. 0.995 x 0.725 x 0.567.
- 45.4. Chinese, Yüan dynasty, 13th-14th century. Image of a Bodhisattva, molded in dry lacquer. Traces of blue, gold, and green paint and of gold leaf. Slightly damaged and repaired. 0.583 x 0.431 x 0.567.
- 45.11. Chinese, T'ang dynasty, 8th-9th century. Figures of two horsewomen, playing polo, carved in wood. Remains of polychrome painting and a white priming coat. Slight damages. 45.11, 0.361 x 0.142 x 0.361. (Illustrated). 45.12, 0.367 x 0.136 x 0.360.

SILVER

- 44.58. Chinese, 8th-9th century. T'ang dynasty. Ladle, with a seven-lobed bowl; the surface covered with delicate engraved ornament. 0.312 (length).

The work of the staff members has been devoted to the study of new acquisitions, of other objects submitted for purchase, and to general research work within the collections of Chinese, Arabic, Persian, and Indian fine arts; the preparation of material for publication and revisions of earlier work. Reports, oral or written, were made upon oriental objects belonging to other institutions or submitted for ex-

amination by private owners, to the total number of 1,918 objects and 110 reproductions of objects. Written translation of 132 oriental language inscriptions were made on request. Docent service and public lectures given by staff members are listed below.

WAR WORK

In addition to their regular curatorial work, a large part of the time of two members of the staff was given to work for other Government agencies directly concerned with war work. One of these members was detached from the Gallery to work at the Office of War Information 4 days a week for a period of 6 months. Other work, involving the correction and revision of official Government publications on China and Japan, was done at the Freer Gallery, where also working space and assistance was given to a group of four persons from the American Committee for the Protection and Salvage of Artistic and Historic Monuments in War Areas, working on the project for Korea. Several individuals from branches of the armed services were assisted in special studies and given 122 photographs. Fifty-eight photographs of Chinese objects in the collection were presented to a representative of the National Library of Peiping.

Repairs to the collection can be summarized as follows:

Chinese paintings remounted.....	243
Tibetan painting remounted.....	1
Chinese lacquer figure repaired.....	1
Chinese stone sculpture repaired.....	1
Chinese wood sculpture repaired.....	1
Persian manuscript page repaired.....	1

Changes in exhibition totaled 1,373, as follows:

American paintings.....	95
Arabic arts:	
Bookbindings.....	6
Manuscripts.....	45
Paintings.....	16
Wood carving.....	3
Armenian manuscripts.....	8
Chinese arts:	
Bamboo, carved.....	4
Bronzes.....	200
Ceramics.....	148
Gold and silver-gilt.....	21
Jade.....	328
Lacquer.....	1
Marble.....	4
Paintings.....	40
Stone sculpture.....	26
East Christian paintings.....	6
Egyptian stone sculpture.....	1
Greek manuscripts.....	4

Indian arts:	
Manuscripts.....	14
Paintings.....	75
Sculptures.....	8
Islamic metalwork.....	32
Korean pottery.....	24
Near Eastern pottery.....	66
Persian arts:	
Bookbindings.....	8
Manuscripts.....	22
Paintings.....	138
Silver.....	4
Syrian glass.....	16

ATTENDANCE

The Gallery has been open to the public every day except Christmas Day and Mondays up to Monday, January 29, 1945, on which day it began to be open to the public 7 days a week.

The total number of visitors coming in at the main entrance was 72,149. Thirty-seven other visitors on Mondays previous to January 29 made a grand total of 72,186. The total attendance on weekdays was 41,671; on Sundays, 30,478. The average weekday attendance was 148; the average Sunday attendance, 586. The highest monthly attendance was in April, with 7,981 visitors; the lowest, in December, with 3,611 visitors.

There were 1,412 visitors to the main office during the year; the purposes of their visits were as follows:

For general information.....	349
To see members of the staff.....	527
To read in the library.....	216
To make tracings and sketches from library books.....	5
To see building and installations.....	12
To make photographs and sketches.....	15
To see exhibition galleries on Monday.....	5
To examine or purchase photographs and slides.....	336
To submit objects for examination.....	228
To see objects in storage.....	263
<i>Washington Manuscripts</i>	23
Far Eastern paintings and textiles.....	53
Near Eastern paintings and manuscripts.....	37
Tibetan paintings.....	1
Indian paintings and manuscripts.....	7
American paintings.....	55
Whistler prints.....	4
Oriental pottery, jade, bronze, lacquer, and bamboo.....	67
Gold Treasure and Byzantine objects.....	7
All sculpture.....	8
Syrian and other glass.....	1

DOCENT SERVICE, LECTURES, MEETINGS

By request, 4 groups met in the study rooms and 4 groups in the exhibition galleries for instruction by staff members; total, 191 persons.

Illustrated lectures given by staff members were as follows:

October 29, 1944-----	National Gallery of Art. "Chinese Porcelains," by Mr. Pope.
November 10-13, 1944-----	Cleveland Museum of Art. "The Character of Islamic Art"; "The Islamic Exhibition (current)"; "Life and Literature in Persian Miniature Painting"; "Persian Figural Textiles of the 16th and 17th centuries"; by Dr. Ettinghausen.
January 21, 1945-----	Freer Gallery auditorium. The Thornton Society of Washington. "James McNeill Whistler and the Peacock Room," by Miss Guest.
February 27, 1945-----	Museum group of the Special Libraries Association meeting in the Y. W. C. A. hall, 614 E Street. "Persian Painting," by Dr. Ettinghausen.
March 24, 1945-----	Chinese Art Society of America, New York. "Chinese Ceramics," by Mr. Pope.
April 18, 1945-----	University of Minnesota, Minneapolis. "Persian Art: A Survey," by Dr. Ettinghausen.
April 19, 1945-----	Minneapolis Institute of Arts. "Persian Miniatures," by Dr. Ettinghausen.
May 23, 1945-----	Dumbarton Oaks Research Library and Collection of Harvard University, Washington, D. C. "The Metamorphosis of the Persian Miniature," by Dr. Ettinghausen.
June 21, 1945-----	The Arts Club of Washington. "Early Chinese Bronzes and Jades," by Miss Guest.

The Extension Service of the United States Department of Agriculture held a meeting in the auditorium on January 5, 1945.

Several official visits away from the city were made by staff members upon request as follows:

Mr. Wenley to examine collections of Chinese art objects at the College of William and Mary, and at the Art Institute of Chicago.

Dr. Ettinghausen to assist at the installation of a Near East exhibition at the Baltimore Museum of Art.

Other official visits made by staff members were to examine objects offered for sale in New York, to attend special exhibitions there, or to engage in some project of research.

PERSONNEL

Richard Ettinghausen appointed associate in Near Eastern art September 1, 1944.

Eliza Maud Hayward appointed clerk-stenographer (CAF-4) September 6, 1944.

Bertha M. Usilton appointed librarian September 25, 1944.

Grace G. Barnett, librarian, resigned on October 19, 1944.

Joseph H. Boswell, sergeant of the guards, who had been at the Freer Gallery from September 1923 until he retired at his own request on June 30, 1943, died at his home December 8, 1944.

E. Harriet Link, clerk-stenographer (CAF-5), transferred to the American Red Cross as hospital staff aide, for service abroad, February 19, 1945.

John A. Pope, detached from the Freer Gallery to go on active duty as Captain, U. S. Marine Corps Reserve, April 7, 1945.

Jewell A. Kidd appointed clerk-stenographer (CAF-5) May 7, 1945.

Grace T. Whitney worked intermittently at the Gallery in the Near East section between October 24, 1944, and June 15, 1945.

Other changes in personnel are as follows:

Appointments: Odell M. Brantley, guard (CPC-4), November 5, 1944; Rufus R. Thompson, guard (CPC-4), by transfer from Smithsonian Institution night force, January 24, 1945; Lynn V. Black, guard (CPC-4), April 12, 1945.

Separations from the service: Florence E. James, intermittent attendant, September 24, 1944; Chauncey H. Houdeshel, guard (CPC-4), March 8, 1945; Emil L. Zorn, senior mechanic (CPC-7), by voluntary transfer to the Bureau of Aeronautics, Navy Department, February 1, 1945; James W. Burns, guard (CPC-4), retired on account of disability May 31, 1945.

Respectfully submitted.

A. G. WENLEY, *Director.*

Dr. A. WETMORE,

Secretary, Smithsonian Institution.

APPENDIX 5

REPORT ON THE BUREAU OF AMERICAN ETHNOLOGY

SIR: I have the honor to submit the following report on the field researches, office work, and other operations of the Bureau of American Ethnology during the fiscal year ended June 30, 1945, conducted in accordance with the act of Congress of June 27, 1944, which provides "* * * for continuing ethnological researches among the American Indians and the natives of Hawaii and the excavation and preservation of archeologic remains. * * *"

During the fiscal year emphasis on activities concerned with the war effort and with Latin America has continued. It is hoped that as the need for war studies becomes less, the Bureau may soon resume its normal functions.

SYSTEMATIC RESEARCHES

Dr. M. W. Stirling, Chief of the Bureau, left Washington for Mexico on January 29, 1945, to continue the work of the Smithsonian Institution-National Geographic Society archeological project in southern Mexico. From February 24 to March 6 a reconnaissance trip was made in the vicinity of Tapachula, Chiapas, during which a number of archeological sites were located. Two of these, at Caca-huatan and at San Geronimo, contained carved stone monuments.

From March 6 to May 24 excavations were conducted at the site of Piedra Parada, Chiapas, 12 miles north of the town of Ocozocoautla. Most of the work was conducted on a large earth mound which covered a complex stone-masonry structure, but a number of excavations were also made at other points in the site. Previous to inaugurating this work, and at intervals during its progress, trips were made to a number of limestone caves in the vicinity, all of which had been used as places of offering and contained large quantities of ceramic remains. The material from the caves belonged to the same relatively early period as that from the mound site.

From May 28 to May 31 a new and large site of the La Venta culture was discovered as a result of information received from Juan Del Alto, of Coatzacoalcos. It is located on the Río Chiquito in southern Veracruz, near the small village of Tenochtitlan, on lands known as San Lorenzo. The site contains two large mound groups and a considerable number of carved monuments, including the two largest colossal heads of La Venta type yet discovered. Unique fea-

tures at the site are a stone aqueduct and a stone fount in the form of a swimming duck, decorated with water symbols.

Dr. Stirling returned to Washington on June 17, 1945.

Dr. John P. Harrington, ethnologist, prepared during the fiscal year 12 articles on American Indian linguistic subjects. Outstanding among these is one on the Guaraní language of South America, produced through collaboration with Dr. G. T. Bertoni, and one on the Quechua language, written with the help of Prof. J. M. B. Farfán of Lima, Perú. A large proportion of Dr. Harrington's time throughout the year was spent in translating letters and documents in obscure languages for the Office of Censorship.

During the fiscal year Dr. Frank H. H. Roberts, Jr., archeologist, continued to work on the material obtained from the Lindenmeier site in northern Colorado—the location where a group of so-called Folsom men camped during the closing stages of the last glacial period—expanding his studies to include comparisons with artifacts from other sites attributable to early archeological horizons in the New World. In this connection he prepared a manuscript "The New World Paleo-Indian" for publication in the Annual Report of the Smithsonian Institution for 1944, an article "A Deep Burial on the Clear Fork of the Brazos River" for the Bulletin of the Texas Archeological and Paleontological Society, and a paper "An Early Texan" for the Scientific Monthly.

In March 1945 Dr. Roberts was designated as liaison officer between the Smithsonian Institution and the Committee for the Recovery of Archaeological Remains—a group representing the Society for American Archaeology, the American Anthropological Association, and the American Council of Learned Societies—which was organized for the purpose of providing ways and means for the recovery of materials that may be lost through the construction of dams and the flooding of large areas along many of the river systems throughout the United States. Dr. Roberts attended all meetings of this Committee, presenting the Institution's viewpoint and assisting in the drafting of plans for carrying out such a recovery program. Dr. Roberts devoted considerable time during the latter months of the fiscal year to a study of the maps and project reports of the Corps of Engineers and the Bureau of Reclamation for the dams which they plan to construct, and to research in the archeological literature relating to these areas in an effort to determine the districts where sites will be inundated and where provisions should be made for survey and excavation projects.

In accord with the Smithsonian Institution's policy of cooperation with the Library of Congress, Dr. Roberts annotated four books on anthropological subjects for the United States Quarterly Book List. He also continued to serve as a member of the Institution's Personnel

Utilization Committee and as a part of this work prepared a manuscript for a handbook "Smithsonian Institution—Information for Employees." In addition he was the general department representative on the Efficiency Rating Review Board for the Smithsonian Institution, and attended the United States Civil Service Commission's Fourth Annual Institute of Efficiency Rating Boards of Review in June 1945.

On September 22, 1944, Dr. Roberts was appointed Assistant Chief, and during absences of the Chief served as Acting Chief of the Bureau.

Dr. Henry B. Collins, Jr., ethnologist, continued his work in connection with the Ethnogeographic Board. As in the previous year, he handled requests for information on geographical and other subjects which came to the Board from the Army, Navy, and other war agencies. When Dr. Wm. Duncan Strong resigned as Director in July, Dr. Collins was made Acting Director, and at the first Board meeting thereafter, in December, he was appointed Director.

At the invitation of the sponsoring committee, Dr. Collins attended a meeting held in Montreal in September for the purpose of organizing the Arctic Institute of North America. The purpose of the Institute is to initiate, encourage, and support scientific research in Alaska, Canada, and Greenland, on the premise that studies in many fields of science will be required as the basis for efficient planning for the development of the Arctic and sub-Arctic regions of North America. As one of the governors of the Arctic Institute, Dr. Collins attended several meetings in Montreal, at which plans for the operations of the organization were formulated.

During such time as was available, Dr. Collins continued his researches on the archeology of the Eskimo and related problems.

Dr. William N. Fenton, ethnologist, for the fourth successive year continued to devote a large part of the year to activities arising from the war effort. As research associate for the Ethnogeographic Board, six reports on Area Studies in American Universities were completed and issued in mimeograph form; others are in manuscript. These reports cover a survey of Army training programs undertaken in 1944, and again considerable time was spent in travel to the universities while observing the programs and interviewing teachers and trainees. The reception that greeted reports already distributed indicates that they are not without some usefulness.

Scientific activities, although still of necessity somewhat curtailed, picked up toward the end of the year. Dr. Fenton was reelected secretary of the Anthropological Society of Washington, and was appointed to the Board of Editors of the Journal of the Washington Academy of Sciences, to serve for 3 years. Field researches on the Iroquois were resumed. Through a grant from the Viking Fund of

New York, Dr. Fenton visited the Six Nations Reserve near Brantford, Canada, between April 23 and May 19. The Archive of American Folk Song, of the Library of Congress, again furnished recording equipment, enabling Dr. Fenton to make complete sound recordings of the chants of the Iroquois Condolence Council, previously uncollected, Chanters for the Dead, and several social dances. While in Canada, Dr. Fenton visited Toronto to consult with anthropologists at the University concerning a postwar plan for Iroquois studies, and certain specimens were studied at the Royal Ontario Museum of Archaeology.

In addition to reports issued by the Ethnogeographic Board, several book reviews, notes, and articles were contributed to scientific and literary journals. A series on "Place Names and Related Activities of the Cornplanter Senecas" appeared during 1945 in the *Pennsylvania Archaeologist*. The Northwest Ohio Quarterly carried a "Commentary on Samuel Crowell's Account of Seneca Dog Sacrifice near Sandusky (1830)." A second paper, by J. N. B. Hewitt, "Some Mnemonic Pictographs Relating to the Iroquois Condolence Council," was completed by Dr. Fenton in the field and accepted for publication in the *Journal of the Washington Academy of Sciences*, being in proof at the close of the fiscal year. Considerable progress may be noted on a related manuscript, which is a field report on "A Cayuga Condolence Cane with Pictographs Denominating the Founders of the Iroquois League," a project that was undertaken in 1943 for the Cranbrook Institute of Science.

Near the close of the fiscal year, Dr. Fenton visited Harrisburg, Warren, and Philadelphia, Pa., for the purpose of furthering ethnological studies among the Cornplanter and Allegany Senecas in cooperation with the staff of the Pennsylvania Historical Commission, local historians in northwestern Pennsylvania and southwestern New York, and the University of Pennsylvania.

In connection with projected research in the prehistory of river valleys, Dr. Fenton prepared a plan for "An Anthropological Survey of the Allegheny River Reservoir Area of New York and Pennsylvania."

Dr. H. G. Barnett, anthropologist, has devoted his efforts during the fiscal year to studies concerning the general problem of cultural change. Data bearing on this problem were obtained in the past in the field from various Indian communities and are supplemented by diverse historical sources such as regional histories, diaries, pioneer reminiscences, missionary accounts, church records, and a host of official reports on Indian investigations and reservation administration. The Indian communities involved include those of the Yurok and Hupa in northern California, the Siletz and Klamath in Oregon, and the Yakima, as well as several smaller groups around the southern

end of Puget Sound, in the State of Washington. Two publications are contemplated. It is expected that one of them, now in preparation, will be completed at an early date.

Dr. Gordon R. Willey, anthropologist, spent a large part of the fiscal year in editorial work on the *Handbook of South American Indians*, translating and revising manuscript material and selecting and preparing illustrations. He also began and completed the study of several large collections of archeological specimens from south Florida. These collections, now in the United States National Museum, came from sites in Palm Beach, Broward, and Dade Counties, and were excavated by Gene M. Stirling and Lloyd C. Reichard, representatives of the Bureau of American Ethnology, during the years 1933-1936, as a part of the Federal Relief program in archeology. The field operations were conducted by Mr. Stirling and Mr. Reichard, and their notes, drawings, and photographs were used by Dr. Willey in the preparation of the final report, entitled "Excavations in Southeast Florida," which will be published in the Yale University series in anthropology. The manuscript totaled approximately 50,000 words, and included several tables, 8 line drawings, maps, and 17 colotype illustrations.

During the last few months of the fiscal year, a part of Dr. Willey's official duties were given over to preliminary preparations for archeological research in Perú. This projected program calls for a co-operative investigation of the Virú Valley of northern Perú. Columbia University, Yale University, and the Bureau of American Ethnology are the proposed participants. Actual research and results of research will be undertaken and published separately by the participants; collaboration will be in the form of common service functions, such as field laboratories, transportation, and aerial photography. The work is planned for the spring and summer of 1946.

INSTITUTE OF SOCIAL ANTHROPOLOGY

The Institute of Social Anthropology was created in 1943, as an autonomous unit of the Bureau of American Ethnology, to carry out cooperative training in anthropological teaching and research with the other American republics. As the Director, Dr. Julian H. Steward, was instructed in the official order establishing the Institute to report to the Secretary of the Smithsonian Institution, there is presented here his report to Secretary Wetmore.

The Institute of Social Anthropology, carrying out a program of cultural and scientific cooperation with the American republics under a grant transferred from the Department of State, continued under the directorship of Dr. Julian H. Steward. Dr. Alfred Métraux, Assistant Director, was transferred to the War Department on April 2, 1945, to accept an assignment for work in Europe. Miss Ethelwyn

Carter served as secretary throughout the year. Dr. Henry J. Bruman, cultural geographer, who had been on leave of absence since July 17, 1944, resigned on June 30, 1945.

In Mexico, the Institute was represented by Dr. George M. Foster, Jr., anthropologist, and Dr. Roland D. Brand, cultural geographer, cooperating with the Escuela Nacional de Antropología of the Instituto Nacional de Antropología e Historia. From August to December they taught at the Escuela, and from December to June they supervised a party doing field research among Tarascan villages in Michoacán. The field party consisted of students from Mexico and from several other American republics.

In Perú, the Institute was represented by Dr. John P. Gillin, anthropologist, until his resignation January 31, 1945, to resume his teaching duties at Duke University. Dr. Gillin spent approximately 6 months making a study of Moche, a north coast Indian community. Mr. Harry Tschopik, Jr., anthropologist, joined the staff of the Institute on January 1, 1945, and was assigned to the field office in Lima, Perú. In cooperation with the Museos Históricos, under the direction of Dr. Luis Valcárcel, he supervised a field party consisting of representatives of the Museos Históricos in making a cultural survey of the central Highlands of Perú in the region of Huánuco.

An agreement was concluded with the Escola Livre de Sociologia e Politica, of São Paulo, Brazil, for cooperation in teaching and research in the social anthropology of Brazil. Representatives of the Institute of Social Anthropology are to be detailed to Brazil at a later date.

Arrangements for cooperative work in Colombia remained uncompleted.

Publication Number 1 of the Institute of Social Anthropology, "Houses and House Use of the Sierra Tarascans," by Ralph L. Beals, Pedro Carrasco, and Thomas McCorkle, was made available for distribution. Publication Number 2, "Cherán, a Sierra Tarascan Village," by Ralph L. Beals, was received in galley proof from the printer. Publication Number 3, "Moche, a Peruvian Coastal Community," by John P. Gillin, and Publication Number 4, "Cultural and Historical Geography of Southwest Guatemala," by Felix Webster McBryde, were sent to the printer.

Of the \$61,132 originally allocated by the Department of State to the Institute of Social Anthropology for the fiscal year 1945, \$3,500 was transferred back to the Department of State and \$2,500 transferred to the Handbook of South American Indians for the purchase of an extra 600 copies of volume 3 to be distributed by the Department of State. From the remaining amount, \$51,418 was actually obligated, making a saving of \$3,714.

In June 1945 the Smithsonian Institution accepted a grant of \$2,500 from the Office of Inter-American Affairs to be allotted to Dr. Gregorio Hernández de Alba of Bogotá, Colombia, for work on the anthropology of Colombia.

HANDBOOK OF SOUTH AMERICAN INDIANS

Work continued on the Handbook of South American Indians. Volume 1, "The Marginal Tribes," was received in page proof and volume 2, "The Andean Civilizations," in galley proof from the printer; volume 3, "The Tropical Forest Tribes," and volume 4, "The Circum-Caribbean Tribes," were completed and sent to the printer; and volume 5, "Comparative Anthropology of South American Indians," is in the final stages of preparation.

Mrs. Lucille E. Levine, stenographer, resigned on April 10, 1945, and Dr. Gordon R. Willey was transferred to the Bureau of American Ethnology from the roll of the Handbook of South American Indians on August 17, 1944.

For the completion of the Handbook of South American Indians, \$6,000 was transferred from the Department of State. An additional \$2,500 was authorized by the Department of State to be transferred to the Handbook to purchase 600 extra copies of volume 3 for distribution by the Department of State from the amount originally allocated to the Institute of Social Anthropology. Of this total amount, \$8,482 was actually obligated.

SPECIAL RESEARCHES

Because of lack of funds, no special researches were conducted during the fiscal year.

EDITORIAL WORK AND PUBLICATIONS

The editorial work of the Bureau continued during the year under the immediate direction of the editor, M. Helen Palmer. There were issued one Annual Report, one Bulletin, one special publication, and one paper in the Institute of Social Anthropology series, as follows:

Sixty-first Annual Report of the Bureau of American Ethnology, 1943-1944. 9 pp.

Bulletin 142. The contemporary culture of the Cáhita Indians, by Ralph L. Beals. xii+244 pp., 20 pls., 33 figs., 1 map.

List of Publications of the Bureau of American Ethnology, with index to authors and titles. Revised to June 30, 1944. 68 pp.

Institute of Social Anthropology Publ. No. 1. Houses and house use of the Sierra Tarascans, by Ralph L. Beals, Pedro Carrasco, and Thomas McCorkle. 37 pp., 8 pls., 20 figs.

The following publications were in press at the close of the fiscal year:

Bulletin 137. The Indians of the Southeastern United States, by John B. Swanton.

Bulletin 143. Handbook of South American Indians. Julian H. Steward, editor. Volume 1: The Marginal tribes. Volume 2: The Andean civilizations. Volume 3: The Tropical Forest tribes. Volume 4: The Circum-Caribbean tribes.

Publications distributed totaled 11,570.

In addition to the regular work, the editorial staff of the Bureau continued work on the publications of the Institute of Social Anthropology.

LIBRARY

There has been no change in the library staff during the fiscal year. Accessions during the year totaled 204. There has been a large increase in gifts, both spontaneous and on our request. Aside from one large gift which came to us as a unit, both types of gifts are double the number received during the previous fiscal year. Exchanges also much increased over last year and material is beginning to come in from the various countries of western Europe now that postal service is once more established. Several foreign serial sets have been brought up to date by missing numbers supplied, sometimes in long runs, so that our serial sets are in a very good position, considering the disturbed conditions of the past 5 years.

The routine of accessioning and cataloging new material has been kept up to date, and the checklist for the supplement to the last edition of the Union List of Serials was checked for new entries and errors and returned to the editor.

ILLUSTRATIONS

During the year E. G. Cassedy, illustrator, continued the preparation of illustrations, maps, and drawings for the publications of the Bureau and for those of other branches of the Institution.

COLLECTIONS

Collections transferred by the Bureau of American Ethnology to the Department of Anthropology, United States National Museum, during the fiscal year were as follows:

*Accession
No.*

168052. Collection of spoons and fishhooks from Indians of the northwest Pacific coast of British Columbia and southeast Alaska; also a bone skin scraper from the Alaskan Eskimo. From the estate of David I. Bushnell, Jr.
168260. Collection of arrows, skin quivers, and headdresses from the Hupa Indians, Humboldt County, Calif., collected by E. G. Johnson.

*Accession**No.*

168929. Ethnological specimens collected by J. N. B. Hewitt from the Iroquois Indians of the Six Nations Reserve, Grand River, Ontario, Canada, and by James Mooney from the Cherokee of North Carolina.

MISCELLANEOUS

During the course of the year information was furnished by members of the Bureau staff in reply to numerous inquiries concerning the North American Indians, both past and present, and the Mexican peoples of the prehistoric and early historic periods. Various specimens sent to the Bureau were identified and data on them furnished for their owners.

Personnel.—Dr. John R. Swanton, ethnologist, who retired on June 30, 1944, was tendered an appointment to the honorary position of collaborator on July 4, 1944. This action was taken in recognition of Dr. Swanton's long and distinguished services to the Bureau. Dr. Gordon R. Willey was appointed on August 16, 1944, as anthropologist, by transfer from the staff of the Handbook of South American Indians. Dr. Frank H. H. Roberts, Jr., was appointed Assistant Chief of the Bureau on September 22, 1944.

Respectfully submitted.

M. W. STIRLING, *Chief.*

Dr. A. WETMORE,
Secretary, Smithsonian Institution.

APPENDIX 6

REPORT ON THE INTERNATIONAL EXCHANGE SERVICE

SIR: I have the honor to submit the following report on the activities of the International Exchange Service for the fiscal year ended June 30, 1945:

There was allocated for the expenses of the Service \$28,166, an increase over the amount for the last year of \$2,029.

The Institution no longer enjoys the use of the franking privilege in transmitting packages through the mails, that privilege to Government departments having been discontinued. This change in the regulations of the Post Office Department has increased considerably the work in the Exchange office as well as the cost of distributing packages formerly sent under frank but now requiring postage.

The number of packages passing through the Service during the year was 386,758, a decrease from last year of 21,006. The weight of these packages was 211,160 pounds, a decrease of 32,020 pounds. For statistical purposes this material is classified as follows:

	Packages		Weight	
	Sent abroad	Received from abroad	Sent abroad	Received from abroad
United States parliamentary documents sent abroad.....	292, 444	-----	<i>Pounds</i> 100, 802	<i>Pounds</i> -----
Publications received in return for parliamentary documents.....	-----	326	-----	1, 323
United States departmental documents sent abroad.....	47, 238	-----	49, 004	-----
Publications received in return for departmental documents.....	-----	879	-----	3, 121
Miscellaneous scientific and literary publications sent abroad.....	40, 192	-----	46, 764	-----
Miscellaneous scientific and literary publications received from abroad for distribution in the United States.....	-----	5, 679	-----	10, 146
Total.....	379, 874	6, 884	196, 570	14, 590
Grand total.....	386,758		211,160	

Packages are forwarded abroad partly by freight to exchange bureaus for distribution, and partly by mail direct to their destinations. The number of boxes shipped abroad was 983, an increase over last year of 334. Of these, 462 were for depositories of full sets of United States governmental documents. The number of packages sent by mail to foreign countries was 61,038.

Although the war in Europe ended in the latter part of the fiscal year, it has not yet been possible to resume the regular sending of consignments to the liberated countries. However, the Institution was able to forward through the Office of War Information the boxes that had accumulated here for France (182), Italy (134), and Belgium (107). It also succeeded in sending through the United States Despatch Agent in New York, Howard Fyfe, the accumulations for Sweden (111), Palestine (28), and Egypt (12). Regular shipments to these countries, however, have not yet been started. The countries to which consignments are being forwarded regularly remain the same as at the close of last year, namely:

Eastern Hemisphere:

Great Britain and Northern Ireland.
 Republic of Ireland.
 Portugal.
 Union of Soviet Socialist Republics.
 Africa.
 India.
 Australia.
 New Zealand.

Western Hemisphere: All countries outside of the United States.

Shipments to other countries will be resumed at the earliest date practicable.

FOREIGN DEPOSITORIES OF GOVERNMENTAL DOCUMENTS

The number of sets of United States official publications received for transmission abroad through the Service is 93 (56 full sets and 37 partial sets). The partial set for the National Library of Peiping has been changed to a full set. The depository for Mexico has been changed as indicated in the list.

DEPOSITORIES OF FULL SETS

ARGENTINA: Dirección de Investigaciones, Archivo, Biblioteca y Legislación Extranjera, Ministerio de Relaciones Exteriores y Culto, Buenos Aires.
AUSTRALIA: Commonwealth Parliament and National Library, Canberra.
NEW SOUTH WALES: Public Library of New South Wales, Sydney.
QUEENSLAND: Parliamentary Library, Brisbane.
SOUTH AUSTRALIA: Public Library of South Australia, Adelaide.
TASMANIA: Parliamentary Library, Hobart.
VICTORIA: Public Library of Victoria, Melbourne.
WESTERN AUSTRALIA: Public Library of Western Australia, Perth.
BELGIUM: Bibliothèque Royale, Bruxelles.
BRAZIL: Instituto Nacional do Livro, Rio de Janeiro.
CANADA: Library of Parliament, Ottawa.
MANITOBA: Provincial Library, Winnipeg.
ONTARIO: Legislative Library, Toronto.
QUEBEC: Library of the Legislature of the Province of Quebec.

CHILE: Biblioteca Nacional, Santiago.

CHINA: Bureau of International Exchange, Ministry of Education, Chungking
PEIPING: National Library of Peiping.

COLOMBIA: Biblioteca Nacional, Bogotá.

COSTA RICA: Oficina de Depósito y Canje Internacional de Publicaciones, San José.

CUBA: Ministerio de Estado, Canje Internacional, Habana.

CZECHOSLOVAKIA: Bibliothèque de l'Assemblée Nationale, Prague.

DENMARK: Kongelige Danske Videnskabernes Selskab, Copenhagen.

EGYPT: Bureau des Publications, Ministère des Finances, Cairo.

ESTONIA: Riigiraamatukogu (State Library), Tallinn.

FINLAND: Parliamentary Library, Helsinki.

FRANCE: Bibliothèque Nationale, Paris.

GERMANY: Reichstauschstelle im Reichsministerium für Wissenschaft, Erziehung und Volksbildung, Berlin, N. W. 7.

PRUSSIA: Preussische Staatsbibliothek, Berlin, N. W. 7.

GREAT BRITAIN:

ENGLAND: British Museum, London.

LONDON: London School of Economics and Political Science. (Depository of the London County Council.)

HUNGARY: Library, Hungarian House of Delegates, Budapest.

INDIA: Imperial Library, Calcutta.

IRELAND: National Library of Ireland, Dublin.

ITALY: Ministero dell'Educazione Nazionale, Rome.

JAPAN: Imperial Library of Japan, Tokyo.

LATVIA: Bibliothèque d'État, Riga.

LEAGUE OF NATIONS: Library of the League of Nations, Geneva, Switzerland.

MEXICO: Secretaría de Relaciones Exteriores, Departamento de Información para el Extranjero, Mexico, D. F.

NETHERLANDS: Royal Library, The Hague.

NEW ZEALAND: General Assembly Library, Wellington.

NORTHERN IRELAND: H. M. Stationery Office, Belfast.

NORWAY: Universitets-Bibliothek, Oslo. (Depository of the Government of Norway.)

PERU: Sección de Propaganda y Publicaciones, Ministerio de Relaciones Exteriores, Lima.

POLAND: Bibliothèque Nationale, Warsaw.

PORTUGAL: Biblioteca Nacional, Lisbon.

RUMANIA: Academia Română, Bucharest.

SPAIN: Cambio Internacional de Publicaciones, Avenida de Calvo Sotelo 20, Madrid.

SWEDEN: Kungliga Biblioteket, Stockholm.

SWITZERLAND: Bibliothèque Centrale Fédérale, Berne.

TURKEY: Department of Printing and Engraving, Ministry of Education, Istanbul.

UNION OF SOUTH AFRICA: State Library, Pretoria, Transvaal.

UNION OF SOVIET SOCIALIST REPUBLICS: All-Union Lenin Library, Moscow 115.

UKRAINE: Ukrainian Society for Cultural Relations with Foreign Countries, Kiev.

URUGUAY: Oficina de Canje Internacional de Publicaciones, Montevideo.

VENEZUELA: Biblioteca Nacional, Caracas.

YUGOSLAVIA: Ministère de l'Éducation, Belgrade.

DEPOSITORIES OF PARTIAL SETS

AFGHANISTAN: Library of the Afghan Academy, Kabul.

BOLIVIA: Biblioteca del Ministerio de Relaciones Exteriores y Culto, La Paz.

BRAZIL:

MINAS GERAES: Directoria Geral e Estatística em Minas, Belo Horizonte.

BRITISH GUIANA: Government Secretary's Office, Georgetown, Demerara.

CANADA:

ALBERTA: Provincial Library, Edmonton.

BRITISH COLUMBIA: Provincial Library, Victoria.

NEW BRUNSWICK: Legislative Library, Fredericton.

NOVA SCOTIA: Provincial Secretary of Nova Scotia, Halifax.

PRINCE EDWARD ISLAND: Legislative and Public Library, Charlottetown.

SASKATCHEWAN: Legislative Library, Regina.

CEYLON: Chief Secretary's Office, Record Department of the Library, Colombo.

DOMINICAN REPUBLIC: Biblioteca de la Universidad de Santo Domingo, Ciudad Trujillo.

ECUADOR: Biblioteca Nacional, Quito.

GUATEMALA: Biblioteca Nacional, Guatemala.

HAITI: Bibliothèque Nationale, Port-au-Prince.

HONDURAS:

Biblioteca y Archivo Nacionales, Tegucigalpa.

Ministerio de Relaciones Exteriores, Tegucigalpa.

ICELAND: National Library, Reykjavik.

INDIA:

BENGAL: Library, Bengal Legislature, Assembly House, Calcutta.

BIHAR AND ORISSA: Revenue Department, Patna.

BOMBAY: Undersecretary to the Government of Bombay, General Department, Bombay.

BURMA: Secretary to the Government of Burma, Education Department, Rangoon.

PUNJAB: Chief Secretary to the Government of the Punjab, Lahore.

UNITED PROVINCES OF AGRA AND OUDH: University of Allahabad, Allahabad.

IRAN: Imperial Ministry of Education, Tehran.

IRAQ: Public Library, Baghdad.

JAMAICA: Colonial Secretary, Kingston.

LIBERIA: Department of State, Monrovia.

MALTA: Minister for the Treasury, Valleta.

NEWFOUNDLAND: Department of Home Affairs, St. John's.

NICARAGUA: Ministerio de Relaciones Exteriores, Managua.

PANAMA: Ministerio de Relaciones Exteriores, Panama.

PARAGUAY: Ministerio de Relaciones Exteriores, Sección Biblioteca, Asunción.

SALVADOR:

Biblioteca Nacional, San Salvador.

Ministerio de Relaciones Exteriores, San Salvador.

THAILAND: Department of Foreign Affairs, Bangkok.

VATICAN CITY: Biblioteca Apostolica Vaticana, Vatican City, Italy.

INTERPARLIAMENTARY EXCHANGE OF THE OFFICIAL JOURNAL

There are now being sent abroad 60 copies each of the Congressional Record and Federal Register. The Bibliothèque du Senat, Paris, was

added to the list during the year. The countries to which these journals are now being forwarded are given in the following list:

DEPOSITORIES OF CONGRESSIONAL RECORD AND FEDERAL REGISTER

ARGENTINA:

Biblioteca del Congreso Nacional, Buenos Aires.
Cámara de Diputados, Oficina de Información Parlamentaria, Buenos Aires.
Boletín Oficial de la República Argentina, Ministerio de Justicia e Instrucción Pública, Buenos Aires.

AUSTRALIA:

Commonwealth Parliament and National Library, Canberra.
NEW SOUTH WALES: Library of Parliament of New South Wales, Sydney.
QUEENSLAND: Chief Secretary's Office, Brisbane.
WESTERN AUSTRALIA: Library of Parliament of Western Australia, Perth.

BRAZIL:

Biblioteca do Congresso Nacional, Rio de Janeiro.
AMAZONAS: Archivo, Biblioteca e Imprensa Publica, Manáos.
BAHIA: Governador do Estado da Bahia, São Salvador.
ESPÍRITO SANTO: Presidência do Estado do Espírito Santo, Victoria.
RIO GRANDE DO SUL: "A Federação," Porto Alegre.
SERGIPE: Biblioteca Publica do Estado de Sergipe, Aracajú.
SÃO PAULO: Imprensa Oficial do Estado, São Paulo.

BRITISH HONDURAS: Colonial Secretary, Belize.

CANADA:

Library of Parliament, Ottawa.
Clerk of the Senate, Houses of Parliament, Ottawa.

CUBA: Biblioteca del Capitolio, Habana.

FRANCE: Bibliothèque du Senat, Paris.

GREAT BRITAIN: Printed Library of the Foreign Office, London.

GUATEMALA: Biblioteca de la Asamblea Legislativa, Guatemala.

HAITI: Bibliothèque Nationale, Port-au-Prince.

HONDURAS: Biblioteca del Congreso Nacional, Tegucigalpa.

INDIA: Legislative Department, Simla.

IRISH FREE STATE: Dail Eireann, Dublin.

MEXICO:

Dirección General de Información, Secretaría de Gobernación, Mexico, D. F.
Biblioteca Benjamin Franklin, Mexico, D. F.

AGUASCALIENTES: Gobernador del Estado de Aguascalientes, Aguascalientes.

CAMPECHE: Gobernador del Estado de Campeche, Campeche.

CHIAPAS: Gobernador del Estado de Chiapas, Tuxtla Gutierrez.

CHIHUAHUA: Gobernador del Estado de Chihuahua, Chihuahua.

COAHUILA: Periódico Oficial del Estado de Coahuila, Palacio de Gobierno, Saltillo.

COLIMA: Gobernador del Estado de Colima, Colima.

DURANGO: Gobernador Constitucional del Estado de Durango, Durango.

GUANAJUATO: Secretaría General de Gobierno del Estado, Guanajuato.

GUERRERO: Gobernador del Estado de Guerrero, Chilpancingo.

JALISCO: Biblioteca del Estado, Guadalajara.

LOWER CALIFORNIA: Gobernador del Distrito Norte, Mexicali.

MÉXICO: Gaceta del Gobierno, Toluca.

MICHOACÁN: Secretaría General de Gobierno del Estado de Michoacán, Morelia.

MEXICO—Continued.

MORELOS: Palacio de Gobierno, Cuernavaca.

NAYARIT: Gobernador de Nayarit, Tepic.

NUEVO LEÓN: Biblioteca del Estado, Monterrey.

OAXACA: Periódico Oficial, Palacio de Gobierno, Oaxaca.

PUEBLA: Secretaría General de Gobierno, Puebla.

QUERÉTARO: Secretaría General de Gobierno, Sección de Archivo, Querétaro.

SAN LUIS POTOSÍ: Congreso del Estado, San Luis Potosí.

SINALOA: Gobernador del Estado de Sinaloa, Culiacán.

SONORA: Gobernador del Estado de Sonora, Hermosillo.

TABASCO: Secretaría General de Gobierno, Sesión 3a, Ramo de Prensa, Villahermosa.

TAMAULIPAS: Secretaría General de Gobierno, Victoria.

TLAXCALA: Secretaría de Gobierno del Estado, Tlaxcala.

VERACRUZ: Gobernador del Estado de Veracruz, Departamento de Gobernación y Justicia, Jalapa.

YUCATÁN: Gobernador del Estado de Yucatán, Mérida.

NEW ZEALAND: General Assembly Library, Wellington.

PERU: Cámara de Diputados, Lima.

UNION OF SOUTH AFRICA:

CAPE OF GOOD HOPE: Library of Parliament, Cape Town.

TRANSVAAL: State Library, Pretoria.

URUGUAY: Diario Oficial, Calle Florida 1178, Montevideo.

VENEZUELA: Biblioteca del Congreso, Caracas.

FOREIGN EXCHANGE AGENCIES

The French Service of International Exchanges, located for many years at 110 Rue de Grenelle, Paris, is now under the direction of the National Library at 58 Rue de Richelieu.

There is given below a list of bureaus or agencies to which consignments are forwarded in boxes by freight when the Service is in full operation. To all countries not appearing in the list, packages are sent to their destinations by mail.

LIST OF AGENCIES

BELGIUM: Service Belge des Échanges Internationaux, Bibliothèque Royale de Belgique, Bruxelles.

CHINA: Bureau of International Exchange, Ministry of Education, Chungking.

CZECHOSLOVAKIA: Service des Échanges Internationaux, Bibliothèque de l'Assemblée Nationale, Prague 1-79.

DENMARK: Service Danois des Échanges Internationaux, Kongelige Danske Videnskabernes Selskab, Copenhagen V.

EGYPT: Government Press, Publications Office, Bulaq, Cairo.

FINLAND: Delegation of the Scientific Societies of Finland, Kasärngatan 24, Helsinki.

FRANCE: Service Français des Échanges Internationaux, Bibliothèque Nationale, 58 Rue de Richelieu, Paris.

GERMANY: Amerika-Institut, Universitätstrasse 8, Berlin, N. W. 7.

GREAT BRITAIN AND IRELAND: Wheldon & Wesley, 721 North Circular Road, Willesden, London, N. W. 2.

HUNGARY: Hungarian Libraries Board, Ferenciektere 5, Budapest, IV.

INDIA: Superintendent of Government Printing and Stationery, Bombay.

ITALY: Ufficio degli Scambi Internazionali, Ministero dell'Educazione Nazionale, Rome.

JAPAN: International Exchange Service, Imperial Library of Japan, Uyeno Park, Tokyo.

LATVIA: Service des Échanges Internationaux, Bibliothèque d'État de Lettonie, Riga.

NETHERLANDS: International Exchange Bureau of the Netherlands, Royal Library, The Hague.

NEW SOUTH WALES: Public Library of New South Wales, Sydney.

NEW ZEALAND: General Assembly Library, Wellington.

NORWAY: Service Norvégien des Échanges Internationaux, Bibliothèque de l'Université Royale, Oslo.

PALESTINE: Jewish National and University Library, Jerusalem.

POLAND: Service Polonais des Échanges Internationaux, Bibliothèque Nationale, Warsaw.

PORTUGAL: Secção de Trocas Internacionais, Biblioteca Nacional, Lisbon.

QUEENSLAND: Bureau of Exchanges of International Publications, Chief Secretary's Office, Brisbane.

ROMANIA: Ministère de la Propagande Nationale, Service des Echanges Internationaux, Bucharest.

SOUTH AUSTRALIA: South Australian Government Exchanges Bureau, Government Printing and Stationery Office, Adelaide.

SPAIN: Junta de Intercambio y Adquisición de Libros y Revistas para Bibliotecas Públicas, Ministerio de Educación Nacional, Avenida Calvo Sotelo 20, Madrid.

SWEDEN: Kungliga Biblioteket, Stockholm.

SWITZERLAND: Service Suisse des Échanges Internationaux, Bibliothèque Centrale Fédérale, Berne.

TASMANIA: Secretary to the Premier, Hobart.

TURKEY: Ministry of Education, Department of Printing and Engraving, Istanbul.

UNION OF SOUTH AFRICA: Government Printing and Stationery Office, Cape Town, Cape of Good Hope.

UNION OF SOVIET SOCIALIST REPUBLICS: International Book Exchange Department, Society for Cultural Relations with Foreign Countries, Moscow, 56.

VICTORIA: Public Library of Victoria, Melbourne.

WESTERN AUSTRALIA: Public Library of Western Australia, Perth.

YUGOSLAVIA: Section des Échanges Internationaux, Ministère des Affaires Étrangères, Belgrade.

Respectfully submitted.

H. W. DORSEY, *Acting Chief.*

Dr. A. WETMORE,

Secretary, Smithsonian Institution.

APPENDIX 7

REPORT ON THE NATIONAL ZOOLOGICAL PARK

SIR: I have the honor to submit the following report on the operations of the National Zoological Park for the fiscal year ended June 30, 1945:

The Congress appropriated \$334,651 for the operation of the Zoo for the fiscal year. Of this amount, \$296,277 was expended for all purposes, including \$35,562 for overtime pay of employees under the legislative provision that put overtime into effect this year. This leaves an unexpended balance of \$38,374 subject to minor corrections when a few outstanding bills are finally settled. The saving was largely on salaries because of the impossibility of filling vacant positions.

During the war the Zoo has been able to accomplish its primary duty of maintaining an exhibition collection of live animals, and to maintain it at as high a level as ever before in its history. Owing to shortage of manpower, certain phases of the care of the Park were necessarily neglected, and no special improvements were made. The personnel has been fully occupied in maintaining and keeping in order as far as possible the grounds and buildings. An attempt is being made at the present time to increase the staff to prewar numbers.

The United States Marshal's Office has continued to turn over to the Zoo quantities of food condemned for some reason as unfit for human consumption but satisfactory for consumption by certain animals. The managers of some of the larger vegetable stores continue to put aside trimmings for the Zoo, which gives certain of the animals a supply of fresh vegetables and reduces considerably the cost of maintenance.

The Zoo officials have cooperated as far as possible with the various Government agencies, including the War and Navy Departments, and continue to supply facilities for art and biology classes and to furnish information to the public.

NEEDS OF THE ZOO

The most immediate need of the Zoo is an increase of personnel. During the war more than 20 percent of all positions have been vacant. The actual care of the animals has not been neglected, but very little work has been possible in connection with the care and maintenance

of the buildings and grounds. Prior to the war, when the personnel had 1½ days off during the week, the Zoo was short-handed. Now that there is such an accumulation of work, this condition is much more noticeable, and when the 40-hour week goes into effect it will be even worse.

A large backlog of work exists in connection with the restoration of the Park buildings, fences, and other structures. Also, the Park has always been insufficiently policed. A force of 14 policemen is not large enough to patrol an area of 175 acres and to guard the Government buildings and property now in the Park.

The office building now in use is a historic structure built about 1805 but of which little is known prior to 1827. It was used as a residence from then until 1890, when it was taken over by the Park as an office. It is obsolete for an administration building. The fire hazard is considerable and our records and our library are not safe. The barn and garage adjacent to the office building is an ancient frame structure. Modernization of these two buildings would greatly facilitate the work of the office.

It is hoped that the Zoo may continue the building program that was interrupted by the war and replace with modern structures the old unsanitary monkey house, lion house, and antelope house.

VISITORS

There is an increase in the number of visitors, including schools and excursion parties, and it is expected that this increase will continue owing to greater interest in the Zoo and to easier transportation facilities.

A tabulation of cars parked in the Zoo during the fiscal year 1945 shows the following percentage of visitors by States:

	Percent		Percent
Washington, D. C.-----	36	North Carolina-----	1.3
Maryland-----	24.6	New Jersey-----	1.2
Virginia-----	16.1	California-----	1.15
Pennsylvania-----	3.3	Ohio-----	1.1
New York-----	2.3		

The cars that made up the remaining 12.95 percent came from every one of the remaining States, and from the following territories and countries: Canal Zone, Hawaii, Alberta, Ontario, Quebec, Cuba, Mexico.

NUMBER OF VISITORS

July-----	217,300	February-----	138,800
August-----	189,550	March-----	248,700
September-----	181,100	April-----	275,164
October-----	200,500	May-----	159,650
November-----	152,520	June-----	185,200
December-----	85,900		
January-----	72,700	Total-----	2,355,514

NUMBER OF GROUPS FROM SCHOOLS

	<i>Number of groups</i>	<i>Number in groups</i>
Washington, D. C.-----	45	1,904
Maryland-----	29	1,301
Virginia-----	27	884
Pennsylvania-----	1	20
North Carolina-----	1	18
Total-----	103	4,127

ACQUISITION OF SPECIMENS

A few animals are now coming into the market, and the Zoo has been able to add a number of interesting specimens. Chief among these are a collection of attractive West African monkeys and a few birds from South and Central America.

GIFTS

Many interesting specimens have been presented to the Zoo during the year. Among these were a pair of Solomon Islands cockatoos, a red-sided lory, a cardinal parrot, and a Pacific swamp hen presented by Maj. Gen. R. G. Breene, U. S. A.; and black-striped and pretty-faced wallabies from R. A. Bryant, Jr., of Coronado, Calif. Mrs. Erika Cook Bascom brought with her from the Gold Coast a pigmy galago and two green fruit pigeons, rare in captivity. From Señor don Alejandro Caballero Gamboa of San José, Costa Rica, came a collection of brilliant cage birds, sent through Luis Marden of the National Geographic Society, who also presented a trio of Costa Rican turtles.

James Landis, of the Foreign Economic Administration, was presented by the Government of Saudi Arabia with a pair of the rare and beautiful antelope, *Oryx beatrix*, which he sent to the Zoo.

George Ballou of Bethesda, Md., continued to donate various mammals and birds collected during his field work in the south.

DONORS AND THEIR GIFTS

Alderson, Wendell, Marshall Hall, Md., black widow spider.

Allard, H. A., Arlington, Va., opossum.

Andrews Field, Washington, D. C., white-tailed deer.

Andrews, Maj. M. B., Arlington, Va., white-lipped tamarin.

Ansel, Willits, Annapolis, Md., nine-banded armadillo.

Anthony, Frank, Arlington, Va., Cooper's hawk.

Ballou, George, Bethesda, Md., short-tailed shrew, two diamond-back rattlesnakes, two cottonmouth moccasins, six black snakes, cotton rat, mud snake, six garter snakes, two indigo snakes, two blue racer snakes, chicken snake, turkey vulture, five deer mice, meadow mouse.

Bartsch, Paul, Washington, D. C., pilot black snake.

Bascom, Mrs. Erika Cook, Washington, D. C., galago, two green fruit pigeons.

- Beasley, W. M., Washington, D. C., sparrow hawk.
Bell, Mrs. E. H., Alexandria, Va., two Pekin ducks.
Bell, J. R., Washington, D. C., three shaft-tailed finches, three spice finches, three canaries, five society finches, four zebra finches, strawberry finch, olive Cuban finch.
Breene, Maj. Gen. R. G., U. S. A., cardinal parrot, South Pacific swamp hen, two Solomon Islands cockatoos, red-sided lory.
Bresnahan, Polly, Peggy, and Tom, Washington, D. C., two Pekin ducks.
Browning, Charles, Jackson Heights, N. Y., box turtle.
Bryant, R. A., Jr., Coronado, Calif., three wallabies.
Butts, Earl D., Alexandria, Va., long-tailed skunk.
Case, Mrs. George W., Bethesda, Md., horned lizard.
Chittick, Peter, McLean, Va., red bat, three fence lizards.
Cochran, Doris M., Washington, D. C., 2 cascade frogs, 25 local minnows, wood turtle.
Cole, James C., Washington, D. C., 72 goldfish.
Colfield, L., Washington, D. C., six golden pheasants.
Conner, Capt. T. E., U. S. A., hairy armadillo, grison.
Constantinides, George, American Embassy, Lisbon, six chameleons.
Cook, Robert, Washington, D. C., black snake.
Davis, Watson, Washington, D. C., keeled green snake.
Denley, Charles, Washington, D. C., blue-eared Manchurian pheasant.
de Ybarrondo, Mrs. Mova, Washington, D. C., two Pekin ducks.
Dickenson, Philip, Bethesda, Md., four tree toads, snapping turtle.
Dixon, Mrs. Daniel, Washington, D. C., rabbit.
Dowell, Mrs., Colmar Manor, Md., blue peafowl.
Drain, D. R., Belvoir, Va., catbird.
Drown, C. H., Berwyn, Md., red fox.
Druid Hill Park Zoo, Baltimore, Md., two spiny-tailed lizards, bald eagle.
Duffey, C. H., Red Lodge, Mont., three peach-faced love birds.
Dunlap, Capt. S. B., Washington, D. C., two Muscovy ducks.
Dutton, John B., Chevy Chase, Md., opossum and young.
Elliot, Maj. W. E., Arlington, Va., black widow spider.
Ennes, Richard, Washington, D. C., water snake.
Etheridge, James H., Washington, D. C., two nine-banded armadillos.
Ewin, Mrs. James L., Washington, D. C., Pekin duck.
Fernandez, Mrs. Raymond, Washington, D. C., three Pekin ducks.
Fish and Wildlife Service, Billings, Mont., hybrid Canada goose x blue goose.
Fish and Wildlife Service, Brigham, Utah, eight green-winged teal.
Fish and Wildlife Service, Washington, D. C., through Fred Orsinger, Aquarium, 3 golden orf, 5 carp, 50 yellow perch.
Foster, C. W., Fairfax, Va., alligator.
Frantz, Jean H., Bethesda, Md., two Pekin ducks.
Frye, Mrs. Jack, Falls Church, Va., two skunks.
Gamboia, Alejandro C., San José, Costa Rica, two Costa Rican chlorophonia, two blue-hooded euphonia, euphonia, blue honey creeper.
Garrison, Mrs. W. B., Washington, D. C., yellow-headed parrot.
Gatti, Stephen A., Washington, D. C., sparrow hawk.
Gibson, Nolan, Washington, D. C., two barred owls.
Gillmer, Lt. Commander L. C., Annapolis, Md., gray squirrel.
Gude Bros. Co., Washington, D. C., alligator.
Hamlet, John N., Fish and Wildlife Service, Washington, D. C., long-eared owl, turtle, raven, flag ground squirrel.

Hardy, David, Catonsville, Md., copperhead snake.
 Hart, Mrs. J. F., Berryville, Va., turtle.
 Heard, W. A., Jr., Washington, D. C., two Texas ground squirrels.
 Hepburn, Charles, and Neal, William, Washington, D. C., smooth-scaled green snake.
 Hoeke, Mrs. W. L., Washington, D. C., four grass paroquets.
 Hume, Thomas L., Washington, D. C., three Pekin ducks.
 Hutchinson, Fred, Washington, D. C., blue racer snake.
 Irwin, Mickey, Bethesda, Md., Muscovy duck.
 James, C., Cedar Hill Bird Farm, Landover, Md., South American thrush.
 Jarvis, W. O., Washington, D. C., pigeon.
 Johnson, Mrs. Philander, Rockville, Md., mourning dove.
 Johnson, Robert, Washington, D. C., 4 frogs, salamander, 2 green snakes, banded water snake, garter snake, 12 green frogs, blue racer snake.
 Jorgensen, Lorraine, Washington, D. C., two Pekin ducks.
 Joslyn, Marc, Bethesda, Md., Pekin duck.
 Justice, Mr. (?), (address not recorded), double yellow-headed parrot.
 Kent, William and Wallace, Washington, D. C., two red-shouldered hawks.
 Krug, J. A., Washington, D. C., spider monkey.
 Kulick, M/Sgt. F. R., U. S. A., rhesus monkey.
 Kurfess, Ensign J. F., Washington, D. C., Florida banded water snake.
 Lanning, Mrs. John, Cottage City, Md., four barn owls.
 Lavengood, Mrs. T., Washington, D. C., double yellow-headed parrot.
 Lee, Richard H., Washington, D. C., five alligators.
 Lewis, Anna W., Washington, D. C., horned lizard.
 Lewis, Mrs. M. D., Chevy Chase, Md., three mallard ducks.
 Littlepage, Mrs. James H., Washington, D. C., garter snake.
 Locke, Otto Martin, New Braunfels, Tex., four nine-banded armadillos.
 Louis C. Herrington & Co., Orlando, Fla., two African clawed frogs.
 Maiker, Mrs. R. W., Washington, D. C., Pekin duck.
 Mann, William M., Washington, D. C., mole.
 Marcow, Michael M., Washington, D. C., white alligator.
 Marden, Luis, San José, Costa Rica, three Costa Rican turtles.
 Mauer, James R., Linden, Md., four Pekin ducks.
 McDermott, Henry J., Takoma Park, Md., five canaries.
 McNish, John, Chevy Chase, Md., black snake.
 Meikle, Mrs. J. C., Washington, D. C., two Leclancher's buntings.
 Meyer, H. E., Miami, Fla., two green racer snakes, blue-tailed skink, anolis.
 Michael, L. S., Arlington, Va., black widow spider.
 Miller, Gerrit S., Washington, D. C., two box turtles.
 Miller, Luther, Chevy Chase, Md., three Pekin ducks.
 Mitchell, Mrs. John W., Silver Spring, Md., ring-necked snake.
 Naval Air Base, Washington, D. C., chain king snake.
 Neri, Joseph, Washington, D. C., four ring-necked doves.
 Ogus, Dr. William I., Washington, D. C., yellow-headed parrot.
 O'Rourke, Margaret A., Washington, D. C., Pekin duck.
 Patten, James, Washington, D. C., anolis, Cumberland turtle.
 Payne, Mr. and Mrs. J. M., Washington, D. C., two horned lizards.
 Petroskey, E., Washington, D. C., two angora rabbits.
 Pooley, Samuel, National Institute of Health, Washington, D. C., two rice rats.
 Powers, Lt. Arthur J., U. S. A., 6 pilot black snakes, 4 water snakes, 2 garter snakes, 3 hog-nosed snakes, 10 copperhead snakes, ring-necked snake, De Kay's snake, 20 water snakes.

Quillitch, Robert, Arlington, Va., alligator.
 Racey, Mrs. E., Washington, D. C., nine flying squirrels.
 Rayfield, Earl, Washington, D. C., sparrow hawk.
 Renwick, John M., Washington, D. C., raccoon.
 Richtmyer, Mrs. Nelson, Bethesda, Md., two mallard ducks.
 Robertson, Pat, Alexandria, Va., monkey-face owl.
 Rose, Arnold W., Leesburg, Fla., rattlesnake.
 Rose, Mrs. B., Washington, D. C., two grass paroquets.
 Royer, John, Bethesda, Md., mole snake.
 Ruppert, Raymond, Jr., Washington, D. C., eastern skunk.
 Ruthling, Paul, Santa Fe, N. Mex., 37 tiger salamanders.
 Sale, F. B., Washington, D. C., ring-necked dove.
 Saudi Arabia, Government of, through James Landis, Foreign Economic Administration, 2 Arabian oryx.
 Schad, Donald C., Baltimore, Md., cooter turtle.
 Schaefer, Frank J., Middleburg, Va., ocelot.
 Shelby, F., Hillside, Md., two bull snakes, water snake, garter snake.
 Sherwin, A. J., Washington, D. C., Pekin duck.
 Shipp, Ralph, Washington, D. C., black snake.
 Shosteck, Robert, Washington, D. C., three fence lizards, blue skink.
 Smith, Mrs. D. C., Washington, D. C., domestic mice.
 Smith, Virginia, Roanoke, Va., spiny-tailed iguana.
 Sparrough, Mrs. Ethel, Washington, D. C., Pekin duck.
 Spinks, Dr. and Mrs. William H., Washington, D. C., two cooter turtles.
 Stabler, Albert, Jr., Silver Spring, Md., long-tailed fowl, two red jungle fowl.
 Surridge, W. R., Washington, D. C., box turtle.
 Tallant, Montague, Manatee, Fla., coachwhip snake.
 Terbough, John, Arlington, Va., conch.
 Thomas, Chauncey S., Washington, D. C., sea turtle.
 Thompson, Bobby Jane, Brookmont, Md., mallard duck.
 Thompson, Roger L., Washington, D. C., alligator.
 Timmons, Mrs. B. N., Washington, D. C., white rabbit.
 Timmons, Manly B., Troy, S. C., pilot black snake, pilot snake, corn snake, hog-nosed snake.
 Trueblood, W., Andover, N. H., two wood turtles.
 Turner, H., Washington, D. C., hog-nosed snake.
 Upton, Elizabeth, Lanham, Md., cottontail rabbit.
 Valenzuela, Mrs. Rosario, Washington, D. C., western mockingbird.
 Wenley, J. J., Hyattsville, Md., great horned owl.
 Windsor, Mrs. C. C., Washington, D. C., opossum.
 Wilson, Mrs. T. W., Norfolk, Va., rhesus monkey.
 Winton, L., Washington, D. C., weasel.
 Wooten, Edgar A., Buckeye, Ariz., horned lizard.
 Worley, Leonard, Washington, D. C., opossum.
 Zoological Society of San Diego, Calif., seven boa constrictors.

BIRTHS

Notable among the births was a hybrid gibbon, *Hylobates agilis* × *Hylobates lar*. The mother discarded the baby after nursing it for a time, and from then on it was raised by hand. At the present time it is over 11 months old and one of the most popular attractions.

On March 4, 1945, there arrived the first giraffe to be born in the Zoo. This female is the offspring of a pair obtained in 1937 by the National Geographic Society-Smithsonian Institution Expedition. One of our two pairs of chinchillas, the first ever exhibited in the Zoo, gave birth to a litter of three young, and the other pair one young.

Added to our list of hybrids was a baby monkey, the mother a white-faced capuchin, the father probably a brown.

The births and hatchings are listed below:

MAMMALS

Scientific name	Common name	Number
<i>Ammotragus lervia</i>	Aoudad	3
<i>Ateles vellerosus</i>	Mexican spider monkey	1
<i>Axis axis</i>	Axis deer	2
<i>Bibos gaurus</i>	Gaur	1
<i>Bison bison</i>	American bison	2
<i>Bos taurus</i>	British Park cattle	2
<i>Bos taurus</i>	West Highland cattle	1
<i>Cebus capucinus</i>	Capuchin monkey	1
<i>Chinchilla lanigera</i>	Chinchilla	4
<i>Choeropsis liberiensis</i>	Pigmy hippopotamus	1
<i>Dama dama</i>	Fallow deer	1
<i>Dama dama</i>	White fallow deer	2
<i>Dolichotus patagonicus</i>	Patagonian cavy	2
<i>Felis concolor</i>	Puma	2
<i>Felis pardus</i>	Black leopard	1
<i>Felis tigris</i>	Bengal tiger	6
<i>Giraffa camelopardalis</i>	Giraffe	2
<i>Hapale jacchus</i>	Marmoset	2
<i>Hippopotamus amphibius</i>	Hippopotamus	1
<i>Hylobates lar pileatus</i> × <i>Hylobates agilis</i>	Hybrid gibbon	1
<i>Lama glama</i>	Llama	2
<i>Lama pacos</i>	Alpaca	1
<i>Thylogale eugenii</i>	Dama wallaby	1
<i>Myocastor coypu</i>	Coypu	1
<i>Odocoileus virginianus</i>	Virginia deer	1
<i>Oncifelis geoffroyi</i>	Geoffroy's cat	2
<i>Ovis aries</i>	Woolless sheep	2
<i>Ovis europaeus</i>	Mouflon	1
<i>Poephagus grunniens</i>	Yak	2
<i>Pseudois nayaur</i>	Bharal or blue sheep	1
<i>Taurotragus oryx</i>	Eland	1
<i>Thalarcos maritimus</i> × <i>Ursus middendorffi</i>	Hybrid bear	1
<i>Urocyon cinereoargenteus</i>	Gray fox	4

BIRDS

<i>Chenopsis atrata</i>	Black swan	1
<i>Fulica americana</i>	American coot	2
<i>Larus novaehollandiae</i>	Silver gull	5
<i>Taeniopygia castanotis</i>	Zebra finch	11
<i>Turtur risorius</i>	Ring-necked dove	2

Statement of accessions

How acquired	Mam- mals	Birds	Reptiles	Amphib- ians	Fish	Inverte- brates	Total
Presented.....	76	143	162	62	155	4	602
Born or hatched.....	58	21				100	179
Received in exchange.....	8	4	30				42
Purchased.....	18	48	65	6	56		193
Deposited.....	18	2	6				26
Total.....	178	218	263	68	211	104	1,042

Summary

Animals on hand July 1, 1944..... 2,435

Accessions during the year..... 1,042

Total number of animals in collection during the year..... 3,477

Removals for various reasons such as death, exchanges, or return of animals on deposit..... 854

In collection on June 30, 1945..... 2,623

Status of collection

Class	Species	Individuals	Class	Species	Individuals
Mammals.....	209	677	Insects.....	1	100
Birds.....	322	909	Arachnids.....	1	2
Reptiles.....	105	447			
Amphibians.....	21	120	Total.....	686	2,623
Fish.....	27	368			

A list of the animals in the collection follows:

ANIMALS IN THE NATIONAL ZOOLOGICAL PARK, JUNE 30, 1945

MAMMALS

MARSUPIALIA

Didelphiidae:

Didelphis virginiana..... Opossum..... 3

Phalangeridae:

Petaurus breviceps..... Lesser flying phalanger..... 2

Petaurus norfolcensis..... Australian flying phalanger..... 2

Macropodidae:

Dendrolagus inustus..... New Guinea tree kangaroo..... 2

Dendrolagus inustus finschi..... Finsche's tree kangaroo..... 3

Macropus major..... Great gray kangaroo..... 1

Thylogale eugenii..... Dama wallaby..... 3

Wallabia dorsalis..... Black-striped wallaby..... 1

Phascologyidae:

Vombatus ursinus..... Flinders Island wombat..... 1

INSECTIVORA

Soricidae:

Blarina brevicauda..... Short-tailed shrew..... 1

Scalopus aquaticus..... Mole..... 1

CARNIVORA

Felidae:

<i>Acinonyx jubatus</i>	Cheetah.....	1
<i>Felis aurata</i>	Golden cat.....	3
<i>Felis chaus</i>	Jungle cat.....	1
<i>Felis concolor</i>	Puma.....	7
<i>Felis concolor patagonica</i>	Patagonian puma.....	1
<i>Felis concolor</i> × <i>Felis concolor</i> <i>patagonica</i>	North American × South American puma.....	4
<i>Felis leo</i>	Lion.....	6
<i>Felis onca</i>	{ Jaguar.....	4
	{ Black jaguar.....	2
<i>Felis pardalis</i>	Ocelot.....	3
<i>Felis pardus</i>	{ Indian leopard.....	3
	{ Black Indian leopard.....	2
<i>Felis tigris</i>	Bengal tiger.....	3
<i>Felis tigris longipilis</i>	Siberian tiger.....	1
<i>Felis tigris sumatrae</i>	Sumatran tiger.....	4
<i>Lynx rufus</i>	Bay lynx.....	2
<i>Lynx uinta</i>	Bob cat.....	1
<i>Neofelis nebulosa</i>	Clouded leopard.....	1
<i>Oncifelis geoffroyi</i>	Geoffroy's cat.....	3
<i>Oncilla pardinoides</i>	Lesser tiger cat.....	1

Viverridae:

<i>Arctictis binturong</i>	Binturong.....	2
<i>Civettictis civetta</i>	African civet.....	1
<i>Myonax sanguineus</i>	Dwarf civet.....	1
<i>Paradoxurus hermaphroditus</i>	Small-toothed palm civet.....	1

Hyaenidae:

<i>Crocuta crocuta germinans</i>	East African spotted hyena.....	1
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Canidae:

<i>Canis latrans</i>	Coyote.....	1
<i>Canis latrans</i> × <i>familiaris</i>	Coyote and dog hybrid.....	1
<i>Canis lupis nubilus</i>	Plains wolf.....	2
<i>Canis niger rufus</i>	Texas red wolf.....	3
<i>Cuon javanicus sumatrensis</i>	Sumatran wild dog.....	1
<i>Dusicyon culpaeus</i>	South American fox.....	1
<i>Dusicyon (Cerdocyon) thous</i>	South American fox.....	1
<i>Nyctereutes procyonoides</i>	Raccoon dog.....	2
<i>Urocyon cinereoargenteus</i>	Gray fox.....	8
<i>Vulpes fulva</i>	Red fox.....	10

Procyonidae:

<i>Nasua narica</i>	Coatimundi.....	12
<i>Nasua nelsoni</i>	Nelson's coatimundi.....	1
<i>Potos flavus</i>	Kinkajou.....	8
<i>Procyon lotor</i>	{ Raccoon.....	5
	{ Black raccoon.....	7
	{ Raccoon (albino).....	1

Bassariscidae:

<i>Bassariscus astutus</i>	Ring-tail or cacomistle.....	2
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Mustelidae:

<i>Grison</i> sp.....	Grison.....	1
<i>Grisonella huronaz</i>	Grison.....	2
<i>Lutra canadensis vaga</i>	Florida otter.....	1
<i>Lutra (Micraonyx) cinerea</i>	Small-clawed otter.....	1
<i>Martes (Lamprogale) flavigula henricii</i>	Asiatic marten.....	1
<i>Meles meles leptorhynchus</i>	Chinese badger.....	1
<i>Mellivora capensis</i>	Ratel.....	1
<i>Mephitis mephitis nigra</i>	Skunk.....	8
<i>Mustela eversmanni</i>	Ferret.....	2
<i>Mustela frenata noveboracensis</i>	Weasel.....	2
<i>Tayra barbara barbara</i>	White tayra.....	2
<i>Tayra barbara senilis</i>	Gray-headed tayra.....	1

Ursidae:

<i>Euarctos americanus</i>	Black bear.....	4
<i>Euarctos thibetanus</i>	Himalayan bear.....	1
<i>Helarctos malayanus</i>	Malay or sun bear.....	1
<i>Melursus ursinus</i>	Sloth bear.....	1
<i>Thalarctos maritimus</i>	Polar bear.....	3
<i>Thalarctos maritimus</i> × <i>Ursus middendorffi</i>	Hybrid bear.....	4
<i>Tremarctos ornatus</i>	Spectacled bear.....	1
<i>Ursus arctos</i>	European brown bear.....	1
<i>Ursus arctos meridianalis</i>	Caucasus brown bear.....	1
<i>Ursus gyas</i>	Alaska Peninsula bear.....	3
<i>Ursus middendorffi</i>	Kodiak bear.....	3
<i>Ursus sitchensis</i>	Sitka brown bear.....	3

PINNIPEDIA

Otariidae:

<i>Zalophus californianus</i>	Sea lion.....	2
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Phocidae:

<i>Phoca vitulina richardii</i>	Pacific harbor seal.....	2
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PRIMATES

Lemuridae:

<i>Lemur mongoz</i>	Mongoose lemur.....	2
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Callitrichidae:

<i>Callithrix jacchus</i>	White-tufted marmoset.....	5
<i>Callithrix penicillata</i>	Black-tufted marmoset.....	2
<i>Leontocebus rosalia</i>	Lion-headed or golden marmoset.....	1

Saimiridae:

<i>Saimiri sciureus</i>	Titi or squirrel monkey.....	1
<i>Saimiri</i> sp.....	Titi or squirrel monkey.....	1

Cebidae:

<i>Alouatta palliata mexicanus</i>	Howling monkey.....	1
<i>Aotus trivirgatus</i>	Douroucoulis or owl monkey.....	5
<i>Ateles geoffroyi vellerosus</i>	Spider monkey.....	9
<i>Cebus apella</i>	Gray capuchin.....	2
<i>Cebus capucinus</i>	White-throated capuchin.....	2
<i>Cebus fatuellus</i>	Weeping capuchin.....	4
<i>Lagothrix lagotricha</i>	Woolly monkey.....	1

Cercopithecidae:

<i>Cercocebus torquatus atys</i>	Sooty mangabey.....	2
<i>Cercopithecus aethiops pygerythrus</i>	Vervet guenon.....	1
<i>Cercopithecus aethiops sabaeus</i>	Green guenon.....	6
<i>Cercopithecus cephus</i>	Moustached guenon.....	1
<i>Cercopithecus diana</i>	Diana monkey.....	3
<i>Cercopithecus diana roloway</i>	Roloway monkey.....	1
<i>Cercopithecus neglectus</i>	De Brazza's guenon.....	2
<i>Cercopithecus nictitans petaurista</i>	Lesser white-nosed guenon.....	3
<i>Cercopithecus sp</i>	West African guenon.....	1
<i>Gymnopyga maurus</i>	Moor monkey.....	1
<i>Macaca fasciata</i>	Japanese monkey.....	2
<i>Macaca irus mordax</i>	Javan macaque.....	5
<i>Macaca mulatta</i>	Rhesus monkey.....	9
<i>Macaca nemestrina</i>	Pig-tailed monkey.....	2
<i>Macaca philippinensis</i>	Philippine macaque.....	1
<i>Macaca sinica</i>	Toque or bonnet monkey.....	1
<i>Macaca speciosa</i>	Red-faced macaque.....	1
<i>Mandrillus sphinx</i>	Mandrill.....	1
<i>Papio comatus</i>	Chacma.....	1

Hylobatidae:

<i>Hylobates agilis</i>	Sumatran gibbon.....	1
<i>Hylobates agilis</i> × <i>Hylobates lar</i> <i>pileatus</i>	Hybrid gibbon.....	1
<i>Hylobates hoolock</i>	Hoolock gibbon.....	1
<i>Hylobates lar pileatus</i>	Black-capped gibbon.....	1
<i>Symphalangus syndactylus</i>	Siamang gibbon.....	1

Pongidae:

<i>Pan troglodytes</i>	Chimpanzee.....	2
<i>Pan troglodytes verus</i>	West African chimpanzee.....	3
<i>Pongo pygmaeus</i>	Bornean orangutan.....	2
<i>Pongo pygmaeus abelii</i>	Sumatran orangutan.....	1

RODENTIA

Sciuridae:

<i>Callosciurus finlaysoni</i>	Lesser white squirrel.....	2
<i>Citellus tridecemlineatus</i>	13-lined ground squirrel.....	1
<i>Cynomys ludovicianus</i>	Plains prairie dog.....	75
<i>Glaucomyss volans</i>	Flying squirrel.....	14
<i>Marmota monax</i>	Woodchuck or ground hog.....	2
<i>Sciurus aberti</i>	Abert's squirrel.....	2
<i>Tamias striatus</i>	Eastern chipmunk.....	1

Heteromyidae:

<i>Dipodomys ordii</i>	Ord kangaroo rat.....	3
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Cricetidae:

<i>Mesocricetus auratus</i>	Golden hamster.....	13
<i>Microtus pennsylvanicus</i>	Meadow mouse.....	1
<i>Neotoma floridana attwateri</i>	Round-tailed wood rat.....	6
<i>Oryzomys palustris</i>	Rice rat.....	2
<i>Peromyscus crinitus auripectus</i>	Golden-breasted mouse.....	1
<i>Peromyscus leucopus</i>	White-footed or deer mouse.....	1
<i>Sigmodon hispidus</i>	Cotton rat.....	4

Muridae:		
<i>Mus musculus</i>	White and other domestic mice.....	8
<i>Rattus norvegicus</i>	White and pied colored rats.....	1
Hystriidae:		
<i>Acanthion brachyurum</i>	Malay porcupine.....	3
<i>Atherurus africanus</i>	West African brush-tailed porcupine.....	2
<i>Hystrix galeata</i>	African porcupine.....	1
<i>Thecurus crassispinis sumatrae</i>	Thick-spined porcupine.....	1
Myocastoridae:		
<i>Myocastor coypus</i>	Coypu.....	14
Cuniculidae:		
<i>Cuniculus paca virgatus</i>	Central American paca.....	1
Dasyproctidae:		
<i>Dasyprocta croconota prymnolopha</i>	Agouti.....	2
<i>Dasyprocta punctata</i>	Speckled agouti.....	5
Chinchillidae:		
<i>Chinchilla chinchilla</i>	Chinchilla.....	6
Caviidae:		
<i>Cavia porcellus</i>	Guinea pig.....	10
<i>Dolichotis patagona</i>	Patagonian cavy.....	1

LAGOMORPHA

Leporidae:		
<i>Oryctolagus cuniculus</i>	Domestic rabbits.....	15

ARTIODACTYLA

Bovidae:		
<i>Ammotragus lervia</i>	Aoudad.....	10
<i>Anoa depressicornis</i>	Anoa.....	1
<i>Anoa quarleisi-fergusoni</i>	Mountain anoa.....	1
<i>Bibos gaurus</i>	Gaur.....	4
<i>Bison bison</i>	{ American bison.....	13
	{ Albino bison.....	1
<i>Bos indicus</i>	Zebu.....	4
<i>Bos taurus</i>	Texas longhorn steer.....	1
<i>Bos taurus</i>	West Highland or Kyles cattle.....	3
<i>Bos taurus</i>	British Park cattle.....	4
<i>Capra sibirica</i>	Ibex.....	1
<i>Cephalophus maxwellii</i>	Maxwell's duiker.....	1
<i>Cephalophus niger</i>	Black duiker.....	1
<i>Cephalophus nigrifrons</i>	Black-fronted duiker.....	2
<i>Hemitragus jemlahicus</i>	Tahr.....	6
<i>Oreotragus oreotragus</i>	South African klipspringer.....	1
<i>Oryx beatrix</i>	Arabian oryx.....	2
<i>Oryx beisa annectens</i>	Ibean beisa oryx.....	2
<i>Ovis aries</i>	Woolless or Barbadoes sheep.....	2
<i>Ovis europaeus</i>	Mouflon.....	3
<i>Poephagus grunniens</i>	Yak.....	6
<i>Pseudois nayaur</i>	Bharal or blue sheep.....	2
<i>Synceros caffer</i>	African buffalo.....	2
<i>Taurotragus oryx</i>	Eland.....	3

Cervidae:

<i>Axis axis</i>	Axis deer.....	6
<i>Cervus canadensis</i>	American elk.....	5
<i>Cervus elaphus</i>	Red deer.....	6
<i>Dama dama</i>	{ Fallow deer.....	11
	{ White fallow deer.....	13
<i>Muntiacus reevesi</i>	Rib-faced or barking deer.....	1
<i>Odocoileus virginianus</i>	Virginia deer.....	4
<i>Sika Manchuricum</i>	Dybowsky deer.....	3
<i>Sika nippon</i>	Japanese deer.....	3

Giraffidae:

<i>Giraffa camelopardalis</i>	Nubian giraffe.....	5
<i>Giraffa reticulata</i>	Reticulated giraffe.....	1

Camelidae:

<i>Camelus bactrianus</i>	Bactrian camel.....	3
<i>Camelus dromedarius</i>	Single-humped camel.....	1
<i>Lama glama</i>	Llama.....	5
<i>Lama glama guanico</i>	Guanaco.....	2
<i>Lama pacos</i>	Alpaca.....	2
<i>Vicugna vicugna</i>	Vicuna.....	2

Tayassuidae:

<i>Pecari angulatus</i>	Collared peccary.....	1
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Suidae:

<i>Babirusa babirusa</i>	Babirusa.....	2
<i>Phacochoerus aethiopicus aeliani</i>	East African wart hog.....	3

Hippopotamidae:

<i>Choeropsis liberiensis</i>	Pigmy hippopotamus.....	6
<i>Hippopotamus amphibius</i>	Hippopotamus.....	2

PERISSODACTYLA

Equidae:

<i>Equus burchellii antiquorum</i>	Chapman's zebra.....	2
<i>Equus grevyi</i>	Grevy's zebra.....	1
<i>Equus grevyi</i> × <i>asinus</i>	Zebra-ass hybrid.....	1
<i>Equus grevyi</i> × <i>caballus</i>	Zebra-horse hybrid.....	1
<i>Equus kiang</i>	Asiatic wild ass or kiang.....	1
<i>Equus onager</i>	Onager.....	1
<i>Equus przewalskii</i>	Mongolian wild horse.....	3
<i>Equus zebra</i>	Mountain zebra.....	1

Tapiridae:

<i>Acrocodia indica</i>	Asiatic tapir.....	2
<i>Tapirus terrestris</i>	South American tapir.....	1

Rhinocerotidae:

<i>Rhinoceros unicornis</i>	Great Indian one-horned rhinoceros.....	1
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PROBOSCIDAE

Elephantidae:

<i>Elephas maximus sumatranus</i>	Sumatran elephant.....	1
<i>Loxodonta africana oxyotis</i>	African elephant.....	1

EDENTATA

Choloepodidae:		
<i>Choloepus didactylus</i>	Two-toed sloth.....	1
Dasypodidae:		
<i>Chaetophractus villosus</i>	Hairy armadillo.....	2
<i>Euphractus sexcinctus</i>	Six-banded armadillo.....	1

BIRDS

CASUARIIFORMES

Casuariidae:		
<i>Casuarus bennetti papuanus</i>	Papuan cassowary.....	1
<i>Casuarus casuarus aruensis</i>	Aru cassowary.....	1
<i>Casuarus uniappendiculatus occipitalis</i>	Island cassowary.....	1
<i>Casuarus uniappendiculatus uniappendiculatus</i>	One-wattled cassowary.....	1
Rheidae:		
<i>Rhea americana</i>	Common rhea.....	2
Dromiceidae:		
<i>Dromiceus novaehollandiae</i>	Common emu.....	2

SPHENISCIFORMES

Spheniscidae:		
<i>Aptenodytes forsteri</i>	Emperor penguin.....	3
<i>Spheniscus demersus</i>	Jackass penguin.....	4
<i>Spheniscus humboldti</i>	Humboldt penguin.....	2

TINAMIFORMES

Tinamidae:		
<i>Eudromia elegans</i>	Crested tinamou or martineta.....	1

PELECANIFORMES

Pelecanidae:		
<i>Pelecanus conspicillatus</i>	Australian pelican.....	2
<i>Pelecanus erythrorhynchus</i>	White pelican.....	5
<i>Pelecanus occidentalis</i>	Brown pelican.....	5
<i>Pelecanus onocrotalus</i>	European pelican.....	2

Phalacrocoracidae:		
<i>Phalacrocorax auritus albiciliatus</i> ...	Farallon cormorant.....	1
Fregatidae:		
<i>Fregata ariel</i>	Lesser frigate bird.....	1

CICONIIFORMES

Ardeidae:		
<i>Ardea herodias</i>	Great blue heron.....	2
<i>Ardea occidentalis</i>	Great white heron.....	1
<i>Egretta thula</i>	Snowy egret.....	6
<i>Florida caerulea</i>	Little blue heron.....	1
<i>Hydranassa tricolor ruficollis</i>	Louisiana heron.....	2
<i>Notophox novaehollandiae</i>	White-faced heron.....	1
<i>Nycticorax nycticorax naevius</i>	Black-crowned night heron.....	24
Cochleariidae:		
<i>Cochlearius cochlearius</i>	Boatbill heron.....	1

Ciconiidae:

<i>Dissoura episcopus</i>	Woolly-necked stork.....	1
<i>Ibis cinereus</i>	Malay stork.....	2
<i>Leptoptilus crumeniferus</i>	Marabou.....	1
<i>Leptoptilus dubius</i>	Indian adjutant.....	1
<i>Leptoptilus javanicus</i>	Lesser adjutant.....	2
<i>Mycteria americana</i>	Wood ibis.....	1

Threskiornithidae:

<i>Ajaia ajaja</i>	Spoonbill.....	5
<i>Guara alba</i>	White ibis.....	8
<i>Guara alba</i> × <i>G. rubra</i>	Hybrid white and scarlet ibis.....	1
<i>Guara rubra</i>	Scarlet ibis.....	1
<i>Threskiornis aethiopica</i>	Sacred ibis.....	1
<i>Threskiornis melanolephala</i>	Black-headed ibis.....	4
<i>Threskiornis spinicollis</i>	Straw-necked ibis.....	2

Phoenicopteridae:

<i>Phoenicopiterus chilensis</i>	Chilean flamingo.....	2
<i>Phoenicopiterus ruber</i>	Cuban flamingo.....	3

ANSERIFORMES

Anhimidae:

<i>Chauna cristata</i>	Crested screamer.....	7
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Anatidae:

<i>Aix sponsa</i>	Wood duck.....	4
<i>Anas brasiliensis</i>	Brazilian teal.....	2
<i>Anas domestica</i>	Pekin duck.....	20
<i>Anas platyrhynchos</i>	Mallard duck.....	56
<i>Anas rubripes</i>	Black duck.....	7
<i>Anser albifrons</i>	American white-fronted goose.....	1
<i>Anser cinereus domestica</i>	Toulouse goose.....	3
<i>Anseranus semipalmata</i>	Australian pied goose.....	2
<i>Branta canadensis</i>	Canada goose.....	35
<i>Branta canadensis hutchinsii</i>	Hutchin's goose.....	4
<i>Branta canadensis minima</i>	Cackling goose.....	8
<i>Branta canadensis occidentalis</i>	White-cheeked goose.....	27
<i>Branta canadensis</i> × <i>Chen caerulescens</i>	Hybrid Canada goose × blue goose.....	2
<i>Cairina moschata</i>	Muscovy duck.....	13
<i>Casarca variegata</i>	Paradise duck.....	1
<i>Cereopsis novaehollandiae</i>	Cape Barren goose.....	1
<i>Chen atlantica</i>	Snow goose.....	2
<i>Chen caerulescens</i>	Blue goose.....	2
<i>Chenopsis atrata</i>	Black swan.....	4
<i>Chloephaga leucoptera</i>	Magellan goose.....	2
<i>Cygnopsis cygnoides</i>	Domestic goose.....	2
<i>Cygnus columbianus</i>	Whistling swan.....	2
<i>Cygnus melancoriphus</i>	Black-necked swan.....	1
<i>Cygnus olor</i>	Mute swan.....	5
<i>Dafila acuta</i>	Pintail.....	8
<i>Dafila spinicauda</i>	Chilean pintail.....	1
<i>Dendrocygna arborea</i>	Black-billed tree duck.....	3
<i>Dendrocygna autumnalis</i>	Black-bellied tree duck.....	2
<i>Dendrocygna viduata</i>	White-faced tree duck.....	4

Anatidae—Continued.

<i>Dendronessa galericulata</i>	Mandarin duck.....	4
<i>Mareca americana</i>	Baldpate.....	1
<i>Marila affinis</i>	Lesser scaup.....	1
<i>Marila collaris</i>	Ring-necked duck.....	1
<i>Nettion carolinense</i>	Green-winged teal.....	1
<i>Nettion formosum</i>	Baikal teal.....	5
<i>Nyroca</i> sp.....	Hybrid duck.....	1
<i>Nyroca valisineria</i>	Canvasback duck.....	1
<i>Philacte canagica</i>	Emperor goose.....	3
<i>Querquedula discors</i>	Blue-winged teal.....	8

FALCONIFORMES

Cathartidae:

<i>Cathartes aura</i>	Turkey vulture.....	1
<i>Coragyps atratus</i>	Black vulture.....	1
<i>Gymnogyps californianus</i>	California condor.....	1
<i>Vultur gryphus</i>	Andean condor.....	1

Accipitridae:

<i>Buteo borealis</i>	Red-tailed hawk.....	6
<i>Buteo lineatus elegans</i>	Southern red-shouldered hawk.....	1
<i>Buteo lineatus lineatus</i>	Red-shouldered hawk.....	4
<i>Buteo melanoleucus</i>	South American buzzard eagle.....	2
<i>Buteo platypterus</i>	Broad-winged hawk.....	1
<i>Buteo poecilochrous</i>	Red-backed buzzard.....	1
<i>Gypohierax angolensis</i>	Fish-eating vulture.....	1
<i>Gyps rueppelli</i>	Ruppell's vulture.....	1
<i>Haliaeetus leucocephalus</i>	Bald eagle.....	6
<i>Haliaeetus indus</i>	Brahminy kite.....	5
<i>Harpia harpya</i>	Harpy eagle.....	2
<i>Hypomorphnus urubitinga</i>	Brazilian eagle.....	1
<i>Milvago chimango</i>	Chimango.....	3
<i>Milvus migrans parasitus</i>	African yellow-billed kite.....	2
<i>Pandion haliaetus carolinensis</i>	Osprey or fish hawk.....	1
<i>Parabuteo unicinctus</i>	One-banded hawk.....	1
<i>Torgos tracheliotus</i>	African eared vulture.....	1

Falconidae:

<i>Cerchneis sparverius</i>	Sparrow hawk.....	5
<i>Daptrius americanus</i>	Red-throated caracara.....	3
<i>Falco peregrinus anatum</i>	Duck hawk.....	1
<i>Polyborus plancus</i>	South American caracara.....	1

GALLIFORMES

Cracidae:

<i>Crax fasciolata</i>	Crested curassow.....	1
<i>Crax rubra</i>	Panama curassow.....	1
<i>Crax sclateri</i>	Sclater's curassow.....	1
<i>Mitu mitu</i>	Razor-billed curassow.....	1

Phasianidae:

<i>Argusianus argus</i>	Argus pheasant.....	2
<i>Callipepla squamata</i>	Scaled quail.....	7
<i>Catreus wallichii</i>	Cheer pheasant.....	2
<i>Chrysolophus amherstiae</i>	Lady Amherst's pheasant.....	1
<i>Chrysolophus pictus</i>	Golden pheasant.....	5
<i>Colinus cristatus</i>	Crested quail.....	2
<i>Colinus ridgwayi</i>	Masked quail.....	2
<i>Colinus virginianus</i>	Bobwhite.....	2
<i>Crossophilus auritum</i>	Blue-eared pheasant.....	1
<i>Gallus gallus</i>	Red jungle fowl.....	2
<i>Gallus gallus</i>	Hybrid red jungle fowl × bantam fowl.....	4
<i>Gallus lafayetti</i>	Ceylonese jungle fowl.....	1
<i>Gallus</i> sp.....	Bantam chicken.....	1
<i>Gallus</i> sp.....	Fighting fowl.....	1
<i>Gallus</i> sp.....	Long-tailed fowl.....	2
<i>Gennaeus albocristatus</i>	White-crested kaleege.....	2
<i>Gennaeus nycthemerus</i>	Silver pheasant.....	5
<i>Hierophasis swinhoii</i>	Swinhoe's pheasant.....	2
<i>Lophophorus impeyanus</i>	Himalayan impeyan pheasant.....	1
<i>Lophortyx californica vallicola</i>	Valley quail.....	2
<i>Lophortyx gambelli</i>	Gambel's quail.....	2
<i>Pavo cristatus</i>	Peafowl.....	5
<i>Phasianus torquatus</i>	{ Ring-necked pheasant.....	6
	{ White ring-necked pheasant.....	1
<i>Phasianus versicolor</i>	Green Japanese pheasant.....	1
<i>Polyplectron napoleonis</i>	Palawan peacock pheasant.....	1
<i>Syrnaticus reevesi</i>	Reeve's pheasant.....	1

Numididae:

<i>Acryllium vulturinum</i>	Vulturine guinea fowl.....	1
<i>Numida</i> sp.....	Guinea fowl.....	2

GRUIFORMES

Rhinochetidae:

<i>Rhinoceros jubatus</i>	Kagu.....	1
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Gruidae:

<i>Anthropoides paradisea</i>	Stanley or paradise crane.....	1
<i>Anthropoides virgo</i>	Demoiselle crane.....	2
<i>Balearica pavonina</i>	West African crowned crane.....	2
<i>Balearica regulorum gibbericeps</i>	East African crowned crane.....	1
<i>Grus leucauchen</i>	White-naped crane.....	1
<i>Grus leucogeranus</i>	Siberian crane.....	2

Rallidae:

<i>Amaurornis phoenicurus</i>	White-breasted rail.....	2
<i>Fulica americana</i>	American coot.....	6
<i>Gallinula chloropus cachinnans</i>	Florida gallinule.....	3
<i>Gallinula chloropus orientalis</i>	Sumatran gallinule.....	1
<i>Limnocolaptes flavirostris</i>	African black rail.....	3
<i>Porphyrio poliocephalus</i>	Gray-headed porphyrio.....	1

Cariamidae:

<i>Cariama cristata</i>	<i>Cariama</i> or <i>seriama</i>	2
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CHARADRIIFORMES

Haematopodidae:

<i>Haematopus ostralegus</i>	European oyster catcher.....	1
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Charadriidae:

<i>Belanopterus chilensis</i>	Chilean lapwing.....	1
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Laridae:

<i>Larus argentatus</i>	Herring gull.....	1
<i>Larus delawarensis</i>	Ring-billed gull.....	1
<i>Larus dominicanus</i>	Kelp gull.....	2
<i>Larus glaucescens</i>	Glaucous-winged gull.....	1
<i>Larus novaehollandiae</i>	Silver gull.....	8

Glariolidae:

<i>Glareola pratincola</i>	Collared pratincole.....	1
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COLUMBIFORMES

Columbidae:

<i>Columba guinea</i>	Triangular spotted pigeon.....	1
<i>Columba livia</i>	Domestic pigeon.....	7
<i>Columba maculosa</i>	Spot-winged pigeon.....	1
<i>Ducula aenea</i>	Green imperial pigeon.....	1
<i>Gallicolumba luzonica</i>	Bleeding-heart dove.....	2
<i>Goura cristata</i>	Selater's crowned pigeon.....	1
<i>Goura victoria</i>	Victoria crowned pigeon.....	1
<i>Leptotila cassini</i>	Cassin's dove.....	1
<i>Leptotila rufaxilla</i>	Scaled pigeon.....	1
<i>Muscadivores paulina</i>	Celebian imperial pigeon.....	1
<i>Streptopelia chinensis</i>	Asiatic collared dove.....	2
<i>Streptopelia chinensis ceylonensis</i>	Lace-necked or ash dove.....	3
<i>Streptopelia tranquebarica</i>	Blue-headed ring dove.....	2
<i>Treron calva</i>	West African fruit pigeon.....	2
<i>Turtur risorius</i>	Ring-necked dove.....	19
<i>Zenaida auriculata</i>	South American mourning dove.....	5
<i>Zenaidura macroura</i>	Mourning dove.....	12

PSITTACIFORMES

Psittacidae:

<i>Agapornis pullaria</i>	Red-faced love bird.....	4
<i>Amazona aestiva</i>	Blue-fronted parrot.....	1
<i>Amazona albifrons</i>	White-fronted parrot.....	1
<i>Amazona auropalliata</i>	Yellow-naped parrot.....	3
<i>Amazona ochrocephala</i>	Yellow-headed parrot.....	3
<i>Amazona oratrix</i>	Double yellow-headed parrot.....	2
<i>Anodorhynchus hyacinthinus</i>	Hyacinthine macaw.....	1
<i>Ara ararauna</i>	Yellow and blue macaw.....	2
<i>Ara macao</i>	Red, blue, and yellow macaw.....	2
<i>Ara militaria</i>	Mexican green macaw.....	1
<i>Aratinga euops</i>	Cuban conure.....	1
<i>Calyptrorhynchus magnificus</i>	Banksian cockatoo.....	1
<i>Coracopsis nigra</i>	Lesser vasa parrot.....	1

Psittacidae—Continued.

<i>Cyanopsittacus spixi</i>	Spix's macaw.....	1
<i>Ducorpsis sanguineus</i>	Bare-eyed cockatoo.....	1
<i>Eclectus pectoralis</i>	Eclectus parrot.....	1
<i>Eolophus roseicapillus</i>	Roseate cockatoo.....	3
<i>Kakatoe alba</i>	White cockatoo.....	2
<i>Kakatoe ducrops</i>	Solomon Islands cockatoo.....	2
<i>Kakatoe galerita</i>	Large sulphur-crested cockatoo.....	2
<i>Kakatoe leadbeateri</i>	Leadbeater's cockatoo.....	1
<i>Kakatoe moluccensis</i>	Great red-crested cockatoo.....	1
<i>Kakatoe sulphurea</i>	Lesser sulphur-crested cockatoo.....	2
<i>Lorius domicella</i>	Rajah lory.....	2
<i>Lorius garrulus</i>	Red lory.....	1
<i>Lorius roratus</i>	Red-sided lory.....	1
<i>Melopsittacus undulatus</i>	Grass paraquet.....	5
<i>Myopsitta monachus</i>	Quaker paraquet.....	1
<i>Nandayus nanday</i>	Nanday paroquet.....	1
<i>Nestor notabilis</i>	Kea.....	1
<i>Pionites xanthomera</i>	Amazonian caique.....	2
<i>Psittacula eupatria</i>	Red-shouldered paroquet.....	3
<i>Psittacula krameri</i>	Kramer's paroquet.....	2
<i>Psittacula longicauda</i>	Long-tailed paroquet.....	2
<i>Tanygnathus muelleri</i>	Mueller's parrot.....	1

CUCULIFORMES

Cuculidae:

<i>Eudynamis scolopaceus</i>	Koel.....	1
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Musophagidae:

<i>Turacus livingstoni</i>	Livingston's turacou.....	1
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STRIGIFORMES

Tytonidae:

<i>Tyto alba pratincola</i>	Barn owl.....	7
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Strigidae:

<i>Bubo virginianus</i>	Great horned owl.....	10
<i>Ketupa ketupu</i>	Malay fish owl.....	1
<i>Nyctea nyctea</i>	Snowy owl.....	1
<i>Otus asio</i>	Screech owl.....	2
<i>Strix varia varia</i>	Barred owl.....	6

COLIIFORMES

Coliidae:

<i>Colius striatus</i>	Streaked mouse bird or coly.....	1
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CORACIIFORMES

Alcedinidae:

<i>Dacelo gigas</i>	Kookaburra.....	2
<i>Halcyon sanctus</i>	Sacred kingfisher.....	1

Momotidae:

<i>Momotus lessoni</i>	Motmot.....	1
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PICIFORMES

Ramphastidae:

<i>Aulacorhynchus sulcatus sulcatus</i>	Groove-billed toucanet.....	1
<i>Pteroglossus aracari</i>	Black-necked aracari.....	1
<i>Pteroglossus torquatus</i>	Aracari toucan.....	1
<i>Ramphastos carinatus</i>	Sulphur-breasted toucan.....	7
<i>Ramphastos piscivorus</i>	Toco toucan.....	1

Capitonidae:

<i>Semnornis ramphastinus</i>	Toucan-billed barbet.....	2
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PASSERIFORMES

Cotingidae:

<i>Rupicola peruviana sanguinolenta</i>	Scarlet cock of the rock.....	2
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Corvidae:

<i>Calocitta formosa</i>	Mexican jay.....	1
<i>Cissa chinensis</i>	Chinese cissa.....	2
<i>Cissilopha yucatanica</i>	Yucatan bluejay.....	5
<i>Corvus albus</i>	White-breasted crow.....	2
<i>Corvus brachyrhynchus</i>	American crow.....	6
<i>Corvus corax principalis</i>	Northern raven.....	2
<i>Corvus cornix</i>	Hooded crow.....	1
<i>Corvus cryptoleucus</i>	White-necked raven.....	1
<i>Corvus insolens</i>	Indian crow.....	3
<i>Cyanocitta cristata</i>	Bluejay.....	1
<i>Cyanocorax chrysops</i>	Urraca jay.....	1
<i>Cyanocorax mystacalis</i>	Moustached jay.....	1
<i>Cyanopica cyana</i>	Azure-winged pie.....	2
<i>Gymnorhina hypoleuca</i>	White-backed piping crow.....	3
<i>Pica pica hudsonica</i>	American magpie.....	11
<i>Urocissa caerulea</i>	Formosan red-billed pie.....	2
<i>Urocissa occipitalis</i>	Red-billed blue magpie.....	1

Paradisaeidae:

<i>Ailuroedus crassirostris</i>	Australian catbird.....	1
<i>Epimachus fastuosus</i>	Sickle-billed bird of paradise.....	1
<i>Ptilonorhynchus violaceus</i>	Satin bowerbird.....	1

Pycnonotidae:

<i>Pycnonotus analis</i>	Yellow-vented bulbul.....	1
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Timaliidae:

<i>Leiothrix luteus</i>	Pekin robin.....	3
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Mimidae:

<i>Melanotis caerulescens</i>	Blue catbird.....	1
<i>Mimus polyglottus leucopterus</i>	Mexican mockingbird.....	1
<i>Toxostoma rufum</i>	Brown thrasher.....	1

Turdidae:

<i>Garrulax pectoralis picticollis</i>	Chinese collared laughing thrush.....	1
<i>Hylocichla mustelina</i>	Wood thrush.....	1
<i>Merula migratorius</i>	Eastern robin.....	1
<i>Turdus grayi</i>	Bonaparte's thrush.....	1
<i>Turdus rufiventris</i>	Argentine robin.....	2

Sturnidae:

<i>Creatophora cinerea</i>	Wattled starling.....	1
<i>Galeopsar salvadorii</i>	Crested starling.....	1
<i>Graculipica melanoptera</i>	White starling.....	1
<i>Sturnus vulgarus</i>	Starling.....	2

Ploceidae:

<i>Diatropura procne</i>	Giant whydah.....	4
<i>Lonchura leucogastroides</i>	Bengalee.....	2
<i>Munia maja</i>	White-headed munia.....	2
<i>Munia malacca</i>	Black-throated munia.....	1
<i>Munia oryzivora</i>	Java sparrow.....	5
<i>Munia punctulatus</i>	Rice bird or nutmeg finch.....	1
<i>Ploceus baya</i>	Baya weaver.....	3
<i>Ploceus intermedius</i>	Black-cheeked weaver.....	5
<i>Ploceus rubiginosus</i>	Chestnut-breasted weaver.....	1
<i>Poephila acuticauda</i>	Long-tailed finch.....	1
<i>Quelea sanginirostris intermedia</i>	Southern masked weaver finch.....	2
<i>Steganura paradisea</i>	Paradise whydah.....	4
<i>Taeniopygia castanotis</i>	Zebra finch.....	6

Coerebidae:

<i>Cyanerpes cyanea</i>	Blue honey creeper.....	1
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Icteridae:

<i>Agelaius assimilis</i>	Cuban red-winged blackbird.....	2
<i>Cassiculus melanicterus</i>	Mexican cacique.....	1
<i>Gymnomystax mexicanus</i>	Giant oriole.....	1
<i>Icterus bullocki</i>	Bullock's troupial.....	2
<i>Icterus icterus</i>	Troupial.....	1
<i>Molothrus bonariensis</i>	Shiny cowbird.....	1
<i>Notiopsar curaeus</i>	Chilean blackbird.....	2
<i>Trupialis defilippi</i>	Military starling.....	4

Thraupidae:

<i>Chlorophonia occipitalis callophrys</i>	Central American chlorophonia.....	2
<i>Piranga bidentata</i>	Orange tanager.....	1
<i>Ramphocelus dimidiatus</i>	Crimson tanager.....	1
<i>Ramphocelus flammigerus</i>	Yellow tanager.....	4
<i>Ramphocelus icteronotus</i>	Yellow-rumped tanager.....	2
<i>Tanagra musica elegantissima</i>	Blue-hooded euphonia.....	2
<i>Thraupis cana</i>	Blue tanager.....	2

Fringillidae:

<i>Amandava amandava</i>	Strawberry finch.....	11
<i>Carpodacus mexicanus</i>	Mexican house finch.....	4
<i>Coryphospingus cucullatus</i>	Red-crested finch.....	2
<i>Cyanocopsa argentina</i>	Argentine blue grosbeak.....	2
<i>Diuca diuca</i>	Diuca finch.....	1
<i>Erythrura psittacea</i>	New Caledonian parrot finch.....	1
<i>Lophospingus pusillus</i>	Black-crested finch.....	3
<i>Melopyrrha nigra</i>	Cuban bullfinch.....	1
<i>Paroaria cucullata</i>	Brazilian cardinal.....	2
<i>Paroaria gularis nigro-genis</i>	Black-eared cardinal.....	3
<i>Passerina amoena</i>	Lazuli bunting.....	4
<i>Passerina cyanea</i>	Indigo bunting.....	2
<i>Passerina leclancherii</i>	Leclancher's bunting.....	2
<i>Passerina versicolor</i>	Blue bunting.....	6
<i>Phrygilus fruticeti</i>	Mourning finch.....	2
<i>Phrygilus gayi</i>	Gay's gray-headed finch.....	2
<i>Serinus canarius</i>	Canary.....	4
<i>Sicalis flaveola</i>	Mysto finch.....	1
<i>Sicalis luteola</i>	Saffron finch.....	2

Fringillidae—Continued.

<i>Sicalis minor</i>	Lesser yellow finch.....	4
<i>Spinus uropygialis</i>	Chilean siskin.....	3
<i>Sporophila aurita</i>	Hick's seed-eater.....	2
<i>Sporophila gutturalis</i>	Yellow-billed seed-eater.....	2
<i>Tiaris olivacea</i>	Mexican grassquit.....	1
<i>Volatinia jacarini</i>	Blue-black grassquit.....	1
<i>Zonotrichia capensis</i>	Chingolo.....	2

REPTILES

LORICATA

Crocodylidae:

<i>Alligator mississippiensis</i>	Alligator.....	14
<i>Alligator sinensis</i>	Chinese alligator.....	3
<i>Caiman latirostris</i>	Broad-snouted caiman.....	1
<i>Caiman sclerops</i>	Spectacled caiman.....	3
<i>Crocodylus acutus</i>	American crocodile.....	4
<i>Crocodylus cataphractus</i>	Narrow-nosed crocodile.....	1
<i>Crocodylus niloticus</i>	African crocodile.....	2
<i>Crocodylus palustris</i>	"Toad" crocodile.....	2
<i>Crocodylus porosus</i>	Salt-water crocodile.....	1
<i>Crocodylus rhombifer</i>	Cuban crocodile.....	1
<i>Osteolaemus tetraspis</i>	Broad-nosed crocodile.....	2

SAURIA

Gekkonidae:

<i>Gekko gekko</i>	Gecko.....	2
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Iguanidae:

<i>Anolis carolinensis</i>	False "chameleon".....	10
<i>Basiliscus vittatus</i>	Banded basilisk.....	3
<i>Iguana iguana</i>	Common iguana.....	2
<i>Phrynosoma cornutum</i>	Horned lizard.....	5
<i>Sceloporus undulatus</i>	Pine or fence lizard.....	6

Anguidae:

<i>Ophisaurus ventralis</i>	Glass snake or legless lizard.....	5
<i>Uromastix acanthinurus</i>	North African spiny-tailed lizard.....	1

Helodermatidae:

<i>Heloderma horridum</i>	Mexican beaded lizard.....	2
<i>Heloderma suspectum</i>	Gila monster.....	6

Teiidae:

<i>Cnemidophorus sexlineatus</i>	Six-lined race runner.....	5
<i>Tupinambis nigropunctatus</i>	Black tegu.....	1

Scincidae:

<i>Egernia cunninghami</i>	Cunningham's skink.....	1
<i>Eumeces fasciatus</i>	Blue-tailed skink.....	2
<i>Tiliqua scincoides</i>	Blue-tongued lizard.....	2

Varanidae:

<i>Varanus komodoensis</i>	Komodo dragon.....	1
<i>Varanus monitor</i>	Indian monitor.....	2
<i>Varanus niloticus</i>	Nile monitor.....	2
<i>Varanus salvator</i>	Sumatran monitor.....	4

SERPENTES

Boidae:

<i>Constrictor constrictor</i>	Boa constrictor.....	2
<i>Constrictor imperator</i>	Central American boa.....	8
<i>Epicrates cenchris</i>	Rainbow boa.....	6
<i>Epicrates crassus</i>	Salamanta.....	1
<i>Epicrates striatus</i>	Haitian boa.....	1
<i>Python molurus</i>	Indian rock python.....	6
<i>Python regius</i>	Ball python.....	1
<i>Python reticulatus</i>	Regal python.....	1
<i>Tropidophis melanurus</i>	Cuban boa.....	1

Colubridae:

<i>Coluber constrictor</i>	Black snake.....	4
<i>Coluber flagellum</i>	Coachwhip.....	2
<i>Cyclagras gigas</i>	Cobra de Paraguay.....	1
<i>Diadophis punctatus</i>	Ring-necked snake.....	1
<i>Drymarchon corais couperi</i>	Indigo snake.....	3
<i>Elaphe guttata</i>	Corn snake.....	5
<i>Elaphe obsoleta</i>	Pilot snake.....	4
<i>Elaphe quadrivittata</i>	Yellow chicken snake.....	4
<i>Natrix piscator</i>	Water snake.....	1
<i>Natrix septemvittata</i>	Queen or moon snake.....	3
<i>Natrix</i> sp.....	Water snake.....	15
<i>Natrix</i> sp.....	Indian water snake.....	1
<i>Ophedrys vernalis</i>	Smooth-scaled green snake.....	30
<i>Pituophis catenifer</i>	Western bull snake.....	1
<i>Pituophis catenifer annectans</i>	San Diego gopher snake.....	1
<i>Pituophis melanoleucus</i>	Bull snake.....	1
<i>Ptyas mucosus</i>	Rat snake.....	1
<i>Storeria dekayi</i>	De Kay's snake.....	1
<i>Thamnophis ordinoides</i>	Western garter snake.....	6
<i>Thamnophis sirtalis</i>	Garter snake.....	10

Elapidae:

<i>Naja melanoleuca</i>	West African cobra.....	1
<i>Naja naja</i>	Indian cobra.....	1
<i>Oxybelis fulgidus</i>	Green tree snake.....	1

Crotalidae:

<i>Agkistrodon mokeson</i>	Copperhead snake.....	7
<i>Agkistrodon piscivorus</i>	Water moccasin.....	2
<i>Crotalus atrox</i>	Texas diamond-backed rattlesnake.....	3
<i>Crotalus horridus horridus</i>	Timber rattlesnake.....	1
<i>Crotalus terrificus</i>	South American rattlesnake.....	5

TESTUDINATA

Chelydidae:

<i>Chelodina longicollis</i>	Australian snake-necked turtle.....	1
<i>Batrachemys nasuta</i>	South American side-necked turtle.....	3
<i>Hydraspis</i> sp.....	South American snake-necked turtle.....	3
<i>Hydromedusa tectifera</i>	Snake-necked turtle.....	16
<i>Platemys platycephala</i>	Flat-headed turtle.....	1

Platysternidae:

<i>Platysternum megacephalum</i>	Large-headed Chinese turtle.....	1
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Pelomedusidae:

<i>Pelomedusa galeata</i>	Common African water tortoise.....	2
<i>Podocnemis expansa</i>	South American river tortoise.....	1

Kinosternidae:

<i>Kinosternon</i> sp.....	Central American musk turtle.....	1
<i>Kinosternon subrubrum</i>	Musk turtle.....	4

Chelydridae:

<i>Chelydra serpentina</i>	Snapping turtle.....	8
<i>Macrochelys temminckii</i>	Alligator snapping turtle.....	1

Testudinidae:

<i>Chrysemys marginata</i>	Western painted turtle.....	5
<i>Chrysemys picta</i>	Painted turtle.....	3
<i>Clemmys guttata</i>	Spotted turtle.....	6
<i>Clemmys insculpta</i>	Wood turtle.....	7
<i>Cyclemys amboinensis</i>	Kura kura box turtle.....	3
<i>Emys blandingii</i>	Blanding's turtle.....	1
<i>Geoclemys subtrijuga</i>	Siamese field turtle.....	1
<i>Geoemyda manni</i>	Costa Rican terrapin.....	3
<i>Graptemys barbouri</i>	Barbour's turtle.....	7
<i>Malaclemys centrata</i>	Diamond-back turtle.....	24
<i>Pseudemys concinna</i>	Cooter.....	3
<i>Pseudemys elegans</i>	Cumberland terrapin.....	2
<i>Pseudemys ornata</i>	Central American water turtle.....	1
<i>Pseudemys rugosa</i>	Cuban terrapin.....	1
<i>Terrapene carolina</i>	Box turtle.....	50
<i>Terrapene major</i>	Florida box turtle.....	4
<i>Terrapene</i> sp.....	Mexican box turtle.....	2
<i>Testudo denticulata</i>	South American land tortoise.....	2
<i>Testudo elegans</i>	Star tortoise.....	2
<i>Testudo ephippium</i>	Duncan Island tortoise.....	1
<i>Testudo hoodensis</i>	Hood Island tortoise.....	3
<i>Testudo tornieri</i>	Soft-shelled land tortoise.....	1
<i>Testudo vicina</i>	Albemarle Island tortoise.....	3

Trionychidae:

<i>Amyda ferox</i>	Soft-shelled turtle.....	6
<i>Amyda triunguis</i>	West African soft-shelled turtle.....	1

AMPHIBIA

CAUDATA

Salamandridae:

<i>Triturus pyrrhogaster</i>	Red salamander.....	3
<i>Triturus torosus</i>	Giant newt.....	2
<i>Triturus vulgaris</i>	Common salamander.....	1

Amphiumidae:

<i>Amphiuma means</i>	Blind eel or congo snake.....	1
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Ambystomidae:

<i>Ambystoma maculatum</i>	Spotted salamander.....	2
<i>Ambystoma tigrinum</i>	Axolotl.....	18

SALIENTIA

Dendrobatidae:

<i>Dendrobates auratus</i>	Arrow-poison frog.....	3
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Bufonidae:

<i>Bufo americanus</i>	Common toad.....	12
<i>Bufo empusus</i>	Sapo de concha.....	8
<i>Bufo marinus</i>	Marine toad.....	6
<i>Bufo pellocephalus</i>	Cuban giant toad.....	3

Ceratophryidae:

<i>Ceratophrys ornata</i>	Horned frog.....	3
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Hylidae:

<i>Acris gryllus</i>	Cricket frog.....	5
<i>Hyla crucifer</i>	Tree frog.....	7

Pipidae:

<i>Pipa americana</i>	Surinam toad.....	2
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Ranidae:

<i>Rana catesbeiana</i>	Bullfrog.....	4
<i>Rana clamitans</i>	Green frog.....	3
<i>Rana occipitalis</i>	West African bullfrog.....	1
<i>Rana pipiens</i>	Leopard frog.....	15
<i>Rana sylvatica</i>	Wood frog.....	3
<i>Xenopus laevis</i>	African clawed frog.....	5

FISHES

<i>Aequidens portalegrensis</i>	Blue acara.....	1
<i>Aphysemion australe</i>	Lyre-tailed fish.....	1
<i>Barbus everetti</i>	Clown barb.....	8
<i>Barbus oligolepis</i>		3
<i>Barbus sumatranus</i>		2
<i>Betta</i> sp.....	Fighting fish.....	19
<i>Carassius auratus</i>	Goldfish.....	120
<i>Cichlasoma festivum</i>	Banded acara.....	1
<i>Corydoras melanistius</i>	Armored catfish.....	1
<i>Corydoras</i> sp.....	Catfish.....	2
<i>Danio malabaricus</i>	Blue danio.....	7
<i>Danio rerio</i>	Zebra fish.....	10
<i>Gymnocorymbus ternetzi</i>	Black tetra.....	4
<i>Hemigrammus</i> sp.....	Tetra Buenos Aires.....	2
<i>Hyphessobrycon innesi</i>	Neon tetra fish.....	3
<i>Kryptopterus bicirrhis</i>	Glass catfish.....	3
<i>Lebistes reticulatus</i>	Guppy.....	100
<i>Lepidosiren paradoxa</i>	South American lungfish.....	2
<i>Macropodus</i> sp.....	Paradise fish.....	20
<i>Mollenisia sphenops</i> sp.....	Victory molly.....	8
<i>Platypoecilus</i>	Red moon.....	20
<i>Platypoecilus maculatus</i>	Black wag-tail moon.....	8
<i>Platypoecilus maculatus</i>	Goldplaties.....	12
<i>Plecostomus</i> sp.....	Armored catfish.....	1
<i>Protopterus annectens</i>	African lungfish.....	2
<i>Pterophyllum scalare</i>	Angel fish.....	1
<i>Serrasalmus ternetzi</i>	Piranha or cannibal fish.....	1
<i>Trichogaster leerii</i>	Blue gourami.....	1
<i>Xiphophorus helleri</i>	{ Swordtail.....	3
	{ Tuxedo swordtail.....	12

ARACHNIDS

<i>Eurypelma</i> sp.....	Tarantula.....	2
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INSECTS

<i>Blabera</i> sp.....	Giant cochroach.....	100
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Respectfully submitted.

W. M. MANN, *Director.*

Dr. A. WETMORE,

Secretary, Smithsonian Institution.

APPENDIX 8

REPORT ON THE ASTROPHYSICAL OBSERVATORY

SIR: I have the honor to submit the following report on the operations of the Astrophysical Observatory for the fiscal year ended June 30, 1945:

The work of the Astrophysical Observatory is conducted on funds received largely from appropriation by Congress, amounting for the fiscal year 1945 to \$44,140, and in part from private sources. There are two divisions:

(1) DIVISION OF ASTROPHYSICAL RESEARCH

This division has its headquarters in Washington, and maintains three field stations for solar observations, at Table Mountain, Calif., Tyrone, N. Mex., and Montezuma, Chile. In Washington the division occupies frame buildings in an enclosure about 15,000 square feet in area just south of the Smithsonian Building. The frame structures have served for many years as the offices and laboratories of the division. During the fiscal year 1945 extensive alterations and repairs were made which provide greatly improved facilities for the work of the division.

Work at Washington.—In the first half of the fiscal year a large part of the time of Mrs. Bond, Mr. Hoover, and the Director was given to a compilation of all solar-constant values for the period October 1939 to January 1945. This compilation is an extension of the great table (table 24) of volume 6 of the *Annals of the Astrophysical Observatory*. The extended table summarizes the important factors employed in the reductions and also gives the preferred solar constant for each day of observation in the 21½-year period July 1923 to January 1945. Inasmuch as this period includes three sunspot minima (July 1923, September 1933, May 1944), and thus covers a complete double sunspot period, it became of interest to study all these results to determine what relationship exists between solar constants and sunspot numbers. A paper summarizing this study (*Smithsonian Misc. Coll.*, vol. 104, No. 12) shows a diametrically opposite relationship between solar-constant values and sunspot numbers in the two halves of the double sunspot period. It is important to discover in the succeeding cycle of sunspots whether this complex relationship will repeat itself. If so, the prediction of solar variation as given in

volume 6 of the Annals (fig. 14) and referred to in the 1944 report will require some modification, since that curve did not include consideration of sunspot effects.

Dr. Abbot and Mr. Hoover constructed and tested a new sensitive radiometer which Mr. Abbot plans to use with the aid of the Mount Wilson 100-inch telescope to study the distribution of energy in the spectra of stars of various types. Definite progress was made in the design of the instrument, and in the control of static charges, which in the past have been most troublesome.

At the request of the United States Weather Bureau, two pyrheliometers belonging to the Bureau were repaired and recalibrated. Also a silver-disk pyrheliometer was built, calibrated, and sold at cost to the Bureau.

Dr. H. Arctowski has continued his studies of the effects of solar-radiation changes upon atmospheric circulation and related atmospheric problems. A paper summarizing this work is in preparation.

Work in the field.—Observations at the three field stations were maintained in spite of the continued manpower shortage. Great credit is due the directors of the stations for carrying the heavy observing load under difficulties. Owing to the serious illness of Mr. Moore, director of the Tyrone station, that station was closed for 8 weeks in the spring of 1945.

War work.—Two sets of experiments were carried out at the request of the Military Planning Division, Office of the Quartermaster General, to determine the surface temperatures attained by various samples of military clothing under conditions similar to those of actual use in the field. For this purpose we employed a special thermoelectric device developed some years ago at the Observatory for the measurement of skin temperatures.

In June 1945 a contract was signed with the Office of the Quartermaster General, under the terms of which the Observatory is to make a detailed study of radiation received from sun and sky at Camp Lee, Va., in connection with a series of tests being made at Camp Lee. The preparation of instruments for this study was in progress at the close of the fiscal year.

(2) DIVISION OF RADIATION AND ORGANISMS

(Report prepared by Dr. Earl S. Johnston, Assistant Director of the Division)

During the early part of the year research connected with war projects was terminated. This work dealt mainly with problems of deterioration of cloth, cardboard, and electrical wire insulation by molds and by ultraviolet light. Contact with these projects is still maintained by Dr. Johnston, who was designated liaison representative of the Institution with the Tropical Deterioration Steering Com-

mittee which comes under the National Defense Research Committee. He also represents the Institution as a technical adviser to the Navy with reference to emergency rescue equipment, which section is now under the United States Coast Guard.

The termination of this emergency work has permitted the resumption of the Division's regular research program. Two of our laboratory rooms have been equipped with apparatus and facilities for the continuation of our studies on photosynthesis and on the wavelength effects of light on growth. It has been found necessary to rebuild much of the CO₂ measuring apparatus and to carry out extensive tests before our fundamental problems could be taken up. These steps are now in process of completion, and four preliminary experiments on wave-length balance and plant growth have been carried out. Two other general problems have been pursued: (1) Influence of light on respiration of the grass seedling, and (2) course of development of the grass seedling as influenced by environmental factors with special attention to the role of radiant energy.

It has been noted previously (Weintraub and Johnston, 1944) that brief illumination of etiolated barley seedlings resulted in a marked increase in rate of carbon dioxide evolution. In attempting to gain information on the mechanism of this effect a study has been made of the reducing sugar content of the plants as influenced by light; no significant change in sugar content was found under the experimental conditions employed. In the course of this work it became necessary to devote considerable time to a study of methods of sugar analysis as applied to plant tissues; some of the findings have been published. Experiments are now in progress on measurement of oxygen consumption concurrent with the carbon dioxide production.

The investigation of grass seedling development has proceeded along several lines. In addition to effects of radiation itself, a study is being made of the role of some other environmental factors such as temperature, nutrient supply, and aeration. Additional data have been obtained regarding the action spectrum of mesocotyl inhibition in oats over a wide range of light intensities; at low intensities a second maximum occurs in the neighborhood of 620 m μ . It is hoped that work on the isolation of the photoreceptive pigments can be resumed shortly. Comparison of the effectiveness of red and of violet light has been made for several other species representing a majority of the tribes of grasses; the responses of all species have been found to be fairly similar to that of *Avena*, thus greatly extending the generality of the earlier results of Weintraub and McAlister (1942). The influence of light on elongation of the grass coleoptile also is being studied; the results to date have demonstrated a marked effect of temperature on the response of this organ to light which causes inhibition at lower temperatures but an apparent stimulation at higher temperatures.

PERSONNEL

On June 30, 1944, Dr. C. G. Abbot, for many years Director of the Astrophysical Observatory, retired from administrative work. L. B. Aldrich was appointed Acting Director, and on April 16, 1945, he succeeded to the post of Director. It is a pleasure to record that Dr. Abbot remains at the Observatory as research associate and that his advice and help continue to be available to the staff.

As of June 1, 1945, L. B. Clark, expert glass blower and technician of the Division of Radiation and Organisms, was placed in charge of the construction of instruments and equipment for both divisions of the Observatory.

PUBLICATIONS

During the fiscal year the following publications on the work of the Observatory were issued:

- ABBOT, C. G., Weather predetermined by solar variation. *Smithsonian Misc. Coll.*, vol. 104, No. 5, July 1944.
- ABBOT, C. G., On the 27.0074-day cycle in Washington precipitation. *Smithsonian Misc. Coll.*, vol. 104, No. 9, February 1945.
- ALDRICH, L. B., Smithsonian pyrheliometry and the Andean volcanic eruptions of April 1932. *Smithsonian Misc. Coll.*, vol. 104, No. 6, July 1944.
- ALDRICH, L. B., Solar radiation observations and volcanic dust. *Nature*, vol. 154, No. 3914, p. 538, London, November 1944.
- WEINTRAUB, R. L., Radiation and plant respiration. *Bot. Rev.*, vol. 10, No. 7, July 1944.
- WEINTRAUB, R. L., Chemotherapeutic agents from microbes. *Ann. Rep. Smithsonian Inst. for 1943*, October 1944.
- WEINTRAUB, R. L., and PRICE, LEONARD, Influence of various substances on sugar determination by copper and ferricyanide reagents. *Smithsonian Misc. Coll.*, vol. 104, No. 10, March 1945.

Respectfully submitted.

L. B. ALDRICH, *Director*.

APPENDIX 9

REPORT ON THE LIBRARY

SIR: I have the honor to submit the following report on the activities of the Smithsonian library for the fiscal year ended June 30, 1945:

In use and also in growth the library continued to reflect the progress of the war during the year just past. As the Army and the Navy moved toward the final objective, occupying territory concerning which they had earlier made a thorough search for significant information, the reference use of the library by the war agencies noticeably decreased. The same reason, too, accounts largely for the drop in the number of loans to outside institutions from 1,363 in 1944 to 840 in 1945. Foreign accessions, on the other hand, took an upward turn late in the year, especially after VE-day, and the number of pieces received through the International Exchange Service was 200 more than in the preceding year, while increasingly larger numbers of publications had begun to come from abroad by mail. It is especially gratifying to note here that some of the European learned societies and museums had been able to continue publication of important series straight through the years of the enemy occupation of their countries.

While its more obvious direct use by the personnel of the war agencies declined, there was no falling off in the demand for the library's less direct and conspicuous but no less important war service by the members of the scientific and technical staff of the Institution, many of whom were continuously busy with war projects requiring their special knowledge. Most of this work was not different in kind from the usual peacetime business of supplying the books and information needed by research workers in making scientific investigations, and no exceptional methods or procedures had to be used to do it. Now and then, however, ingenuity and resourcefulness were taxed to meet an out-of-the-ordinary or specially pressing requirement, sometimes to the temporary disruption of established routine.

A forecast of the approaching end of the war was the return to Washington in 1944 of the rare books and manuscripts that had been removed to Lexington, Va., for safekeeping in 1942. The Institution is deeply indebted both to Washington and Lee University and to the Library of Congress for providing the ideal conditions under

which they were housed and protected during the years of their evacuation. The McCormick Library, in the stacks of which the University so generously gave them storage space, is a fine new fireproof building, and the Library of Congress was so kind as to extend to the Smithsonian material the 24-hour guard service which it maintained over its own material similarly stored there. More fortunate provision for the safekeeping of the Institution's irreplaceable books and manuscripts could not have been made, and nothing was lost or injured in any way.

Not a part of its official business, but a willingly accepted wartime obligation, was the library's agency in receiving and distributing the popular books and magazines which members and friends of the Institution continued to bring in for men and women in the service. The table in the main hall of the Smithsonian building was kept well supplied with "take away" reading matter, and many books were turned over to various service centers in the city.

ACCESSIONS

The first evidences of the returning tide of foreign publications came so late in the year that their number and kind did not greatly affect the picture of the accessions for the year as a whole, especially as there had been a small but continuous falling off of serial publications from abroad in the months before. The accessions division handled altogether 25,914 incoming publications. Of these, 3,878, mostly documents not required in the work of the Institution, were sent directly to the Library of Congress, while duplicates received as gifts or in exchange, and some other publications not needed for immediate use, were either given to other Government libraries or were kept in reserve. All the rest were cataloged, entered in the current periodical records, or assigned to sectional libraries for filing in pamphlet collections.

Of the volumes received, 1,863 were purchased. The exigencies of current peacetime scientific publication usually make it difficult to stretch the book budget far enough to include older works needed to fill gaps in the Institution's working collections of reference books. Narratives and reports of early voyages and travels are especially important to the work of both the National Museum and the Bureau of American Ethnology, containing as they do much direct or incidental information about the animals, plants, and peoples of the regions visited, while many of the older books on natural history, art, crafts, industries, and inventions are constantly required for reference by the different departments of the Museum and the National Collection of Fine Arts. This year, as last, it was possible to buy a few of the

Institution's desiderata in these and related fields when they came into the book markets. Among them were Henri Beraldi's "Les Graveurs du XIX^e Siècle," 12 volumes, Paris, 1885-92; George Dixon's "A Voyage Round the World, but More Particularly to the North-West Coast of America, Performed in 1785, 1786, 1787, and 1788," London, 1789; W. Vincent Legge's "A History of the Birds of Ceylon," London, 1880; Urey Lisiansky's "A Voyage Round the World, in the Years 1803, 4, 5, & 6, Performed by Order of His Imperial Majesty Alexander the First, Emperor of Russia, in the Ship Neva," London, 1814; Samuel Palmer's "A General History of Printing, from the First Invention of It in the City of Mentz," London, 1733; Leo Schidlof's "Die Bildnisminiatur in Frankreich im XVII, XVIII, und XIX Jahrhundert," Vienna, 1911; J. P. Williamson's "English-Dakota Vocabulary," Santee Agency, Nebr., 1871; Francis Willughby's "Ornithologie," London, 1676; William Wood's "Index Entomologicus," new and revised edition, with supplement by J. O. Westwood, London, 1854.

GIFTS

Space does not permit the separate listing of the 3,893 books and papers which members and friends of the Institution so generously gave to the library during the year. Among them were many items that greatly enriched the collections, notably two gifts of more than 200 publications each, on photography, some of them old and rare, which were presented to the division of photography for its sectional library by George R. Goergens, and by the firm of Fuller & d'Albert.

Separates and reprints of their papers are always most welcome gifts from scientific investigators, and our divisional libraries on special subjects are largely built up of such contributions. In spite of the wartime difficulties of publication and transmission, the year's record of the receipt of literature of this sort includes the names of individual donors from most of the countries of North and South America, and from Great Britain, Portugal, Egypt, Turkey, South Africa, Australia, and New Zealand.

EXCHANGES

The Institution's policy of exchange of publications has always been a liberal rather than a rigid one of equivalents, and many of its own publications are sent out without expectation of any return in kind at all. This policy has greatly benefited the library, for it has almost invariably been reciprocated generously by the institutions on the exchange list. During this last war year of paper shortage and small

editions, the library has had reason to feel especially grateful to the issuing institutions who have sent us voluntarily, or upon request, many needed publications over and above the hundreds distributed regularly in routine exchange.

CATALOGING

Current cataloging according to the plan of work adopted last year was well kept up, and it was even possible to do a little recataloging of some of the older, inadequately cataloged material most in demand. The union catalog was considerably improved, and work on it was simplified by adopting some clarifying and labor-saving devices in its arrangement, and by withdrawing from it old donor cards and other extraneous records which were serving no present useful purpose.

There are still many thousands of volumes of older accessions in the different bureau libraries and in special collections that are not represented in the union catalog at all, and a large number of them, especially those in the Museum library, are not adequately cataloged in the unit catalogs of the bureau libraries themselves.

Since its founding, almost a hundred years ago, the Smithsonian Institution is so fortunate as to have acquired exceptionally rich collections of literature in certain special fields of its interests, notably in anthropology, zoology, botany, and geology, in addition to the publications sent as part of the Smithsonian Deposit to the Library of Congress. Provision for the cataloging of this and other material, mostly in the different bureau and sectional libraries of the Institution, has always lagged so far behind its inflow, through the years, that the large accumulated "backlog" of work to be done on it might almost be termed permanent. Certain it is that it cannot be satisfactorily reduced within any predictable future time except by a staff of competent catalogers engaged to do it as a special project.

But only when the library finally has a complete catalog of all the Institution's books, so that it is possible to know exactly what and where they are, can it be the scholarly tool and can its staff give the fully effective service that contemporary scientific and technical research requires.

DUPLICATES

The resources of the library's large collections of duplicates and of other publications on subjects not pertinent to the work of the Institution continue to be drawn upon by other Government libraries, and many parts needed for the completion of sets of scientific serials have been supplied to them. More than 6,000 of these publications,

too, were sent to the Library of Congress to be used for the rehabilitation of destroyed libraries.

PERSONNEL

Changes in personnel were the appointment of Miss Mary L. Fleet on October 16, 1944, to be in charge of serials and binding in the Museum library, succeeding Miss Elizabeth G. Moseley who had resigned on August 31; and the appointment on September 18 of Miss Leona Haviland as a cataloger. By transfer from the division of insects Miss Mathilde M. Carpenter was attached to the library staff on August 31 as biological aid in charge of the sectional library of the division of insects. On October 9 Mrs. Carmen G. Randall, who had been under temporary appointment as library assistant, was transferred to the temporary position of senior bindery aid. Miss Beatrice E. Smith served as a cataloger under temporary appointment from June 30 to August 31, 1944.

NEEDS

Relief for the serious overcrowding of the shelves in all the buildings is the library's most urgent need, and the whole matter of the physical condition and arrangement of all its branches and parts with relation to policies and provisions for their growth and administration in the future needs detailed and careful study.

STATISTICS

Accessions

	Volumes	Total holdings June 30, 1945		Volumes	Total holdings June 30, 1945
Astrophysical Observatory (including Radiation and Organisms).....	207	11,715	National Zoological Park.....	34	4,121
Bureau of American Eth- nology.....	204	34,205	Smithsonian Deposit at the Library of Congress (includ- ing the Langley Aeronauti- cal Library).....	723	576,173
Freer Gallery of Art.....	230	16,866	Smithsonian Office.....	187	31,680
National Collection of Fine Arts.....	407	10,155	Total.....	4,844	1,918,460
National Museum.....	2,852	233,544			

¹ Neither incomplete volumes of periodicals nor separates and reprints from periodicals are included in these figures.

Exchanges

New exchanges arranged.....	218
56 of these were assigned to the Smithsonian Deposit.	
"Wants" received.....	6,671
782 of these were obtained to fill gaps in the Smithsonian Deposit sets.	

Cataloging

Volumes and pamphlets cataloged.....	6,512
Cards filed in catalogs and shelflists.....	35,625

Periodicals

Periodical parts entered----- 12,359
3,340 of these were sent to the Smithsonian Deposit.

Circulation

Loans of books and periodicals----- 10,833

This figure does not include the very considerable intramural circulation of books and periodicals assigned to sectional libraries for filing, of which no count is kept.

Binding

Volumes sent to the bindery----- 2,589
Books repaired at the Institution----- 1,149

Respectfully submitted.

LEILA F. CLARK, *Librarian.*

Dr. A. WETMORE,
Secretary, Smithsonian Institution.

APPENDIX 10

REPORT ON PUBLICATIONS

SIR: I have the honor to submit the following report on the publications of the Smithsonian Institution and the Government branches under its administrative charge during the year ended June 30, 1945:

The Institution published during the year 6 papers in the Smithsonian Miscellaneous Collections; 2 papers in the War Background Studies series; 1 Annual Report of the Board of Regents and pamphlet copies of 23 articles in the Report appendix; and 2 special publications. It also reprinted 2 volumes of the Smithsonian Miscellaneous Collections, 17 War Background Studies papers, and 3 special publications.

Owing to the paper shortage, the Secretary's Report for 1944 was not printed as a separate pamphlet, but was mimeographed, in condensed form, for the use of the Board of Regents. This report, including the financial report of the executive committee of the Board of Regents, will form a part of the Annual Report of the Board of Regents to Congress for the year ended June 30, 1944.

The United States National Museum issued 18 Proceedings papers; 1 Bulletin; and 1 separate paper in the Bulletin series of Contributions from the United States National Herbarium.

The Bureau of American Ethnology issued one Annual Report, one Bulletin, one special publication, and one paper in the Institute of Social Anthropology series.

There were distributed 141,635 copies of the publications, including 24 volumes and separates of the Smithsonian Contributions to Knowledge, 14,420 volumes and separates of the Smithsonian Miscellaneous Collections, 19,686 volumes and separates of the Smithsonian Annual Reports, 56,245 War Background Studies papers, 3,812 Smithsonian special publications, 33,264 volumes and separates of National Museum publications, 11,570 publications of the Bureau of American Ethnology, 6 publications of the National Collection of Fine Arts, 8 publications of the Freer Gallery of Art, 160 reports on the Harriman Alaska Expedition, 23 Annals of the Astrophysical Observatory, 889 reports of the American Historical Association, and 1,528 publications of the Institute of Social Anthropology.

SMITHSONIAN MISCELLANEOUS COLLECTIONS

There were issued six papers in this series, as follows:

VOLUME 104

No. 5. Weather predetermined by solar variation, by C. G. Abbot. 44 pp., 24 figs. (Publ. 3771.) July 3, 1944.

No. 6. Smithsonian pyr heliometry and the Andean volcanic eruptions of April 1932, by L. B. Aldrich. 5 pp. (Publ. 3772.) July 3, 1944.

No. 7. The feeding apparatus of the biting and sucking insects affecting man and animals, by R. E. Snodgrass. 113 pp., 39 figs. (Publ. 3773.) October 24, 1944.

No. 8. A new shipworm from the Panama Canal, by Paul Bartsch. 3 pp., 1 pl. (Publ. 3774.) September 7, 1944.

No. 9. On the 27.0074-day cycle in Washington precipitation, by C. G. Abbot. 2 pp. (Publ. 3800.) February 8, 1945.

No. 10. Influence of various substances on sugar determination by copper and ferricyanide reagents, by Robert L. Weintraub and Leonard Price. 17 pp., 9 figs. (Publ. 3801.) March 28, 1945.

The following volumes were reprinted:

VOLUME 79

World Weather Records, assembled and arranged by H. Helm Clayton. First Reprint. xii+1199 pp. (Publ. 2913.)

VOLUME 90

World Weather Records, 1921-1930, assembled and arranged by H. Helm Clayton. First Reprint. xvii+616 pp. (Pub. 3218.)

WAR BACKGROUND STUDIES

In this series the following papers were issued:

No. 20. China, by A. G. Wenley and John A. Pope. 85 pp., 25 pls., 10 figs. (Publ. 3770.) July 27, 1944.

No. 21. The Aleutian Islands: Their people and natural history. (With keys for the identification of the birds and plants), by Henry B. Collins, Jr., Austin H. Clark, and Egbert H. Walker. 131 pp., 21 pls., 8 figs. (Publ. 3775.) February 5, 1945.

The following War Background Studies papers were reprinted:

No. 1. Origin of the Far Eastern civilizations: A brief handbook, by Carl Whiting Bishop.

No. 2. The evolution of nations, by John R. Swanton.

No. 3. The peoples of the Soviet Union, by Aleš Hrdlička.

No. 4. Peoples of the Philippines, by Herbert W. Krieger.

No. 5. The natural-history background of camouflage, by Herbert Friedmann.

No. 6. Polynesians—explorers of the Pacific, by J. E. Weckler.

No. 7. The Japanese, by John F. Embree.

No. 8. Siam—land of free men, by H. G. Deignan.

No. 9. The native peoples of New Guinea, by M. W. Stirling.

No. 10. Poisonous reptiles of the world: A wartime handbook, by Doris M. Cochran.

No. 11. Egypt and the Suez Canal, by Frank H. H. Roberts, Jr.

No. 12. Are wars inevitable? by John R. Swanton.

No. 13. Alaska: America's continental frontier outpost, by Ernest P. Walker.

No. 14. Islands and peoples of the Indies, by Raymond Kennedy.

No. 15. Iceland and Greenland, by Austin H. Clark.

No. 16. Island peoples of the western Pacific: Micronesia and Melanesia, by Herbert W. Krieger.

No. 17. Burma—gateway to China, by H. G. Deignan.

No. 18 on "The Peoples of India," by William H. Gilbert, and No. 19 on "The Peoples of French Indochina," by Olov Janse, were issued so near the end of the previous fiscal year that no reprints were necessitated.

SMITHSONIAN ANNUAL REPORTS

Report for 1943.—The complete volume of the Annual Report of the Board of Regents for 1943 was received from the Public Printer in October 1944:

Annual Report of the Board of Regents of the Smithsonian Institution showing the operations, expenditures, and conditions of the Institution for the year ended June 30, 1943. xi+609 pp., 141 pls., 64 figs. (Publ. 3741.)

The general appendix contained the following papers (Pubs. 3742–3764):

Solar radiation as a power source, by C. G. Abbot.

Some biological effects of solar radiation, by Brian O'Brien.

The sea as a storehouse, by E. F. Armstrong.

Progress in new synthetic textile fibers, by Herbert R. Mauersberger.

Petroleum geology, by William B. Heroy.

The 1942 eruption of Mauna Loa, Hawaii, by Gordon A. MacDonald.

New metals and new methods, by C. H. Desch.

Oceanography, by Henry C. Stetson.

The ocean current called "The Child," by Eliot G. Mears.

Maps, strategy, and world politics, by Richard Edes Harrison and Robert Strausz-Hupé.

The natural-history background of camouflage, by Herbert Friedmann.

Dangerous reptiles, by Doris M. Cochran.

The plants of China and their usefulness to man, by Egbert H. Walker.

Natural rubber, by O. F. Cook.

Lessons from the Old World to the Americas in land use, by Walter Clay Lowdermilk.

Areal and temporal aspects of aboriginal South American culture, by John M. Cooper.

Origin of the Far Eastern civilizations: A brief handbook, by Carl Whiting Bishop.

Contours of culture in Indonesia, by Raymond Kennedy.

The Arab village community of the Middle East, by Afif I. Tannous.

Chemotherapeutic agents from microbes, by Robert L. Weintraub.

Sulfonamides in the treatment of war wounds and burns, by Charles L. Fox.

The yellow fever situation in the Americas, by Wilbur A. Sawyer.

Some food problems in wartime, by George R. Cowgill.

Report for 1944.—The Report of the Secretary, which included the financial report of the executive committee of the Board of Regents, and which will form part of the Annual Report of the Board of Regents to Congress, was not printed as a separate pamphlet, but was mimeographed, in condensed form, for the use of the Board of Regents.

The Report volume, containing the general appendix, was in press at the close of the year.

SPECIAL PUBLICATIONS

Publications of the Smithsonian Institution issued between July 1, 1939, and July 1, 1944. 18 pp. March 1945.

Classified list of Smithsonian publications available for distribution May 1, 1945, compiled by Helen Munroe. 50 pp. (Publ. 3802.) May 1945.

The following special publications were reprinted:

National Aircraft Collection, by Paul Garber. Fifth Edition. 43 pp., illus. (Publ. 3635.) March 1945.

Brief Guide to the Smithsonian Institution. Sixth Edition. 80 pp., illus. April 1945.

A field collector's manual in natural history, prepared by members of the staff of the Smithsonian Institution. 118 pp., 66 figs. (Publ. 3766.) June 1945.

PUBLICATIONS OF THE UNITED STATES NATIONAL MUSEUM

The editorial work of the National Museum has continued during the year under the immediate direction of the editor, Paul H. Oehser. There were issued 18 Proceedings papers, 1 Bulletin, and 1 separate paper in the Bulletin series of Contributions from the United States National Herbarium, as follows:

PROCEEDINGS: VOLUME 94

No. 3177. Parasitic copepods in the United States National Museum, by Charles Branch Wilson. Pp. 529-582, pls. 20-34. July 10, 1944.

Title page, table of contents, and index. Pp. i-vi, 583-598. December 1, 1944.

VOLUME 95

No. 3179. A collection of birds from northern Guanacaste, Costa Rica, by Alexander Wetmore. Pp. 25-80, pls. 3-6. July 7, 1944.

No. 3180. Studies in Neotropical Mallophaga (III) [Tinamidæ No. 2], by M. A. Carriker, Jr. Pp. 81-235, figs. 1-29. October 10, 1944.

No. 3181. The fishes of the family Characinidae from Venezuela, with descriptions of seventeen new forms, by Leonard P. Schultz. Pp. 235-367, figs. 30-56. September 6, 1944.

No. 3182. New genera and species of oriental and Australian plant bugs in the United States National Museum, by Tsai-Yu Hsiao. Pp. 369-396, fig. 57. August 5, 1944.

No. 3183. New species of buprestid beetles from Trinidad, by W. S. Fisher. Pp. 397-409. July 22, 1944.

No. 3184. The Fulgoroidea, or lanternflies, of Trinidad and adjacent parts of South America, by R. G. Fennah. Pp. 411-520, pls. 7-17. May 24, 1945.

No. 3185. Summary of the collections of amphibians made in Mexico under the Walter Rathbone Bacon Traveling Scholarship, by Edward H. Taylor and Hobart M. Smith. Pp. 521-613, figs. 58-61, pls. 18-32. January 30, 1945.

VOLUME 96

No. 3186. Review of the spider monkeys, by Remington Kellogg and E. A. Goldman. Pp. 1-45, figs. 1-2. November 2, 1944.

No. 3187. A revision of the American clingfishes, family Gobiesocidae, with descriptions of new genera and forms, by Leonard P. Schultz. Pp. 47-77, pl. 1. December 30, 1944.

No. 3188. New beetles of the family Eucnemididae from Central America and the West Indies, by W. S. Fisher. Pp. 79-93. May 8, 1945.

No. 3189. New lanternflies (Fulgoroidea) from South America, by R. G. Fennah. Pp. 95-104, pls. 2-3. May 9, 1945.

No. 3190. The genus *Fundella* Zeller: A contribution toward a revision of the American pyralidoid moths of the family Phycitidae, by Carl Heinrich. Pp. 105-114, pls. 4-6. May 18, 1945.

No. 3191. A new genus and two new species of percoid fishes from New Guinea, family Centropomidae, by Leonard P. Schultz. Pp. 115-121, figs. 3-4. March 6, 1945.

No. 3192. Three new sciaenid fishes of the genus *Ophioscion* from the Atlantic coasts of Central and South America, by Leonard P. Schultz. Pp. 123-137, figs. 5-8. April 25, 1945.

No. 3193. The ichneumon-flies of the genus *Cryptanura* Brullé, mainly Tropical American, by R. A. Cushman. Pp. 139-176. May 23, 1945.

No. 3194. Neotropical lanternflies of the genus *Phrictus* in the United States National Museum, with descriptions of four new species, by John S. Caldwell. Pp. 177-184, pls. 7-10. May 16, 1945.

BULLETINS

No. 185, part 3. Checklist of the coleopterous insects of Mexico, Central America, the West Indies, and South America, compiled by Richard E. Blackwelder. Pp. i-iv, 343-550. May 21, 1945.

CONTRIBUTIONS FROM THE UNITED STATES NATIONAL HERBARIUM

VOLUME 29

Part 2. Mexican phanerogams described by M. E. Jones, by C. V. Morton. Pp. 87-116. Asteraceae described from Mexico and the Southwestern United States by M. E. Jones, 1908-1935, by S. F. Blake. Pp. 117-137. May 21, 1945.

PUBLICATIONS OF THE BUREAU OF AMERICAN ETHNOLOGY

The editorial work of the Bureau has continued under the immediate direction of the editor, M. Helen Palmer. During the year the following publications were issued:

Sixty-first Annual Report of the Bureau of American Ethnology, 1943-1944. 9 pp.

Bulletin 142. The contemporary culture of the Cáhita Indians, by Ralph L. Beals. xii+244 pp., 20 pls., 33 figs., 1 map.

List of Publications of the Bureau of American Ethnology, with index to authors and titles. Revised to June 30, 1944. 68 pp.

INSTITUTE OF SOCIAL ANTHROPOLOGY

Publ. No. 1. Houses and house use of the Sierra Tarascans, by Ralph L. Beals, Pedro Carrasco, and Thomas McCorkle. 37 pp., 8 pls., 20 figs. January 4, 1945.

The following publications were in press at the close of the fiscal year:

BULLETINS

137. The Indians of the Southeastern United States, by John R. Swanton.

143. Handbook of South American Indians: vol. 1, The Marginal tribes; vol. 2, The Andean civilizations; vol. 3, The Tropical Forest tribes; vol. 4, The Circum-Caribbean tribes.

PUBLICATIONS OF THE INSTITUTE OF SOCIAL ANTHROPOLOGY

No. 2. Cherán: A Sierra Tarascan village, by Ralph L. Beals.

No. 3. Moche, a Peruvian coastal community, by John Gillin.

No. 4. Cultural and historical geography of Southwest Guatemala, by Felix Webster McBryde.

REPORT OF THE AMERICAN HISTORICAL ASSOCIATION

The annual reports of the American Historical Association are transmitted by the Association to the Secretary of the Smithsonian Institution and are communicated by him to Congress, as provided by the act of incorporation of the Association. The following reports were issued this year:

Annual report of the American Historical Association for the year 1942. Volume 3, The quest for political unity in world history.

Annual report of the American Historical Association for the year 1943. Volume 1, Proceedings.

The following were in press at the close of the fiscal year: Annual report for 1943, volume 2 (Writings on American History), Annual report for 1944, volume 1 (Proceedings and Guide to American Historical Review, 1895-1945); volume 2 (Calendar of the American Fur Company's papers, 1831-1849, Part 1).

REPORT OF THE NATIONAL SOCIETY, DAUGHTERS OF THE AMERICAN REVOLUTION

The manuscript of the Forty-seventh Annual Report of the National Society, Daughters of the American Revolution, was transmitted to Congress, in accordance with law, October 16, 1944.

ALLOTMENTS FOR PRINTING

The congressional allotments for the printing of the Smithsonian Annual Reports to Congress and the various publications of the Gov-

ernment bureaus under the administration of the Institution were virtually used up at the close of the year. The appropriation for the coming year ending June 30, 1946, totals \$88,500, allotted as follows:

Smithsonian Institution.....	\$16,000
National Museum.....	43,000
Bureau of American Ethnology.....	17,480
National Collection of Fine Arts.....	500
International Exchanges.....	200
National Zoological Park.....	200
Astrophysical Observatory.....	500
American Historical Association.....	10,620
Total.....	88,500

Respectfully submitted.

W. P. TRUE, *Chief, Editorial Division.*

Dr. A. WETMORE,

Secretary, Smithsonian Institution.

REPORT OF THE EXECUTIVE COMMITTEE OF THE BOARD OF REGENTS OF THE SMITH- SONIAN INSTITUTION

FOR THE YEAR ENDED JUNE 30, 1945

To the Board of Regents of the Smithsonian Institution:

Your executive committee respectfully submits the following report in relation to the funds of the Smithsonian Institution, together with a statement of the appropriations by Congress for the Government bureaus in the administrative charge of the Institution.

SMITHSONIAN ENDOWMENT FUND

The original bequest of James Smithson was £104,960 8s. 6d.—\$508,318.46. Refunds of money expended in prosecution of the claim, freights, insurance, etc., together with payment into the fund of the sum of £5,015, which had been withheld during the lifetime of Madame de la Batut, brought the fund to the amount of \$550,000.

Since the original bequest, the Institution has received gifts from various sources, the income from which may be used for the general work of the Institution. These, including the original bequest, plus savings, are listed below, together with the income for the present year.

ENDOWMENT FUNDS

(Income for unrestricted use of the Institution)

Partly deposited in U. S. Treasury at 6 percent and partly invested in stocks, bonds, etc.

	Investment	Income present year
Parent Fund (original Smithson bequest, plus accumulated savings).....	\$728,861.07	\$43,700.66
Subsequent bequests, gifts, etc., partly deposited in the U. S. Treasury and partly invested in the Consolidated Fund:		
Avery, Robert S. and Lydia, bequest fund.....	51,245.40	2,129.04
Endowment, from gifts.....	292,397.35	10,118.80
Habel, Dr. S., bequest fund.....	500.00	30.00
Hachenberg, George P. and Caroline, bequest fund.....	4,022.71	139.23
Hamilton, James, bequest fund.....	2,903.78	163.98
Henry, Caroline, bequest fund.....	1,209.71	41.87
Hodgkins, Thomas G. (general) gift.....	146,230.09	8,006.25
Rhees, William Jones, bequest fund.....	1,063.20	51.78
Sanford, George H., memorial fund.....	1,990.41	96.82
Witherspoon, Thomas A., memorial fund.....	129,080.31	4,467.40
Special fund, stock in reorganized closed banks.....	1,400.00	70.00
	632,042.96	25,315.17
Total.....	1,360,904.03	69,015.83

The Institution holds also a number of endowment gifts, the income of each being restricted to specific use. These, plus accretions to date, are listed below, together with income for the present year.

	Investment	Income present year
Abbott, William L., fund, for investigations in biology	\$104,891.63	\$3,534.38
Arthur, James, fund, for investigations and study of the sun and lecture on same	40,002.69	1,384.47
Bacon, Virginia Purdy, fund, for traveling scholarship to investigate fauna of countries other than the United States	50,112.54	1,734.36
Baird, Lucy H., fund, for creating a memorial to Secretary Baird	24,082.45	833.48
Barstow, Frederick D., fund, for purchase of animals for the Zoological Park	760.86	26.34
Canfield Collection fund, for increase and care of the Canfield collection of minerals	38,256.02	1,324.02
Casey, Thomas L., fund, for maintenance of the Casey collection and promotion of researches relating to Coleoptera	9,174.28	317.62
Chamberlain, Francis Lea, fund, for increase and promotion of Isaac Lea collection of gems and mollusks	28,167.08	974.85
Eickemeyer, Florence Brevoort, fund, for preservation and exhibition of photographic collection of Rudolph Eickemeyer, Jr.	507.43	17.66
Hillyer, Virgil, fund, for increase and care of Virgil Hillyer collection of lighting objects	6,573.76	227.51
Hitchcock, Dr. Albert S., Library fund, for care of Hitchcock Agrostological Library	1,478.29	51.16
Hodgkins fund, specific, for increase and diffusion of more exact knowledge in regard to nature and properties of atmospheric air	100,000.00	6,000.00
Hrdlička, Aleš and Marie, fund, to further researches in physical anthropology and publication in connection therewith	21,061.75	311.70
Hughes, Bruce, fund, to found Hughes alcove	19,145.79	662.62
Long, Annette and Edith C., fund, for upkeep and preservation of Long collection of embroideries, laces, etc.	543.13	18.80
Myer, Catherine Walden, fund, for purchase of first-class works of art for the use and benefit of the National Collection of Fine Arts	18,960.17	656.20
National Collection of Fine Arts, Julia D. Strong bequest fund, for benefit of National Collection of Fine Arts	10,000.31	346.11
Pell, Cornelia Livingston, fund, for maintenance of Alfred Duane Pell collection	7,414.19	256.61
Poore, Lucy T. and George W., fund, for general use of the Institution when principal shall amount to \$250,000	96,268.43	4,008.96
Rathbun, Richard, Memorial Fund, for use of division of U. S. National Museum containing Crustacea	\$10,282.15	\$355.86
Reid, Addison T., fund, for founding chair in biology in memory of Asher Tunis	30,055.94	1,388.70
Roebbling fund, for care, improvement, and increase of Roebbling collection of minerals	120,716.53	4,177.93
Rollins, Miriam and William, fund, for investigations in physics and chemistry	93,927.33	3,252.52
Smithsonian employees' retirement fund	64,656.17	2,237.71
Springer, Frank, fund, for care, etc., of Springer collection and library	17,937.03	620.79
Walcott, Charles D. and Mary Vaux, research fund, for development of geological and paleontological studies and publishing results thereof	430,367.55	13,460.66
Younger, Helen Walcott, fund, held in trust	50,118.79	2,517.96
Zerbee, Frances Brinckle, fund, for endowment of aquaria	761.25	26.35
Total	1,396,223.54	50,725.13

The above funds amount to a total of \$2,757,127.57, and are carried in the following investment accounts of the Institution:

U. S. Treasury deposit account, drawing 6 percent interest	\$1,000,000.00
Consolidated investment fund (income in table below)	1,454,957.73
Real estate, mortgages, etc.	250,815.01
Special funds, miscellaneous investments	51,354.83
Total	2,757,127.57

CONSOLIDATED FUND

This fund contains substantially all of the investments of the Institution, with the exception of those of the Freer Gallery of Art; the

deposit of \$1,000,000 in the United States Treasury, with guaranteed income of 6 percent; and investments in real estate and real estate mortgages. This fund contains endowments for both unrestricted and specific use. A statement of principal and income of this fund for the last 10 years follows:

Fiscal year	Principal	Income	Percent- age	Fiscal year	Principal	Income	Percent- age
1936-----	\$723,795.46	\$26,836.61	3.71	1941-----	\$1,093,301.51	\$41,167.38	3.76
1937-----	738,858.54	33,819.43	4.57	1942-----	1,270,968.45	46,701.98	3.67
1938-----	867,528.50	34,679.64	4.00	1943-----	1,316,533.49	50,524.22	3.83
1939-----	902,801.27	30,710.53	3.40	1944-----	1,372,516.41	50,783.79	3.69
1940-----	1,081,249.25	38,673.29	3.47	1945-----	1,454,957.73	50,046.67	3.50

CONSOLIDATED FUND

Gain in investments over year 1944

Investments made from gifts and savings on income-----	\$63,858.97
Investments of gain from sales, etc., of securities-----	18,582.35
Total-----	82,441.32

FREER GALLERY OF ART FUND

Early in 1906, by deed of gift, Charles L. Freer, of Detroit, gave to the Institution his collection of Chinese and other Oriental objects of art, as well as paintings, etchings, and other works of art by Whistler, Thayer, Dewing, and other artists. Later he also gave funds for the construction of a building to house the collection, and finally in his will, probated November 6, 1919, he provided stock and securities to the estimated value of \$1,958,591.42, as an endowment fund for the operation of the Gallery.

The above fund of Mr. Freer was almost entirely represented by 20,465 shares of stock in Parke, Davis & Co. As this stock advanced in value, much of it was sold and the proceeds reinvested so that the fund now amounts to \$5,864,061.73, in a selected list of securities classified later.

The invested funds of the Freer bequest are under the following headings:

Court and grounds fund-----	\$656,922.55
Court and grounds maintenance fund-----	164,994.12
Curator fund-----	668,523.81
Residuary legacy fund-----	4,373,621.25
Total-----	5,864,061.73

Statement of principal and income for the last 10 years

Fiscal year	Principal	Income	Percent- age
1936.....	\$4, 651, 867. 07	\$259, 420. 73	5. 39
1937.....	4, 881, 986. 96	280, 969. 53	5. 75
1938.....	4, 820, 777. 31	255, 651. 61	5. 30
1939.....	5, 075, 976. 76	212, 751. 73	4. 19
1940.....	6, 112, 953. 46	242, 573. 92	3. 96
1941.....	6, 030, 586. 91	233, 079. 22	3. 86
1942.....	5, 912, 878. 64	241, 557. 77	4. 08
1943.....	5, 836, 772. 01	216, 125. 07	3. 70
1944.....	5, 881, 402. 17	212, 395. 27	3. 61
1945.....	5, 864, 061. 73	212, 552. 69	3. 62

FREER FUND

Loss during present year from sale, call of securities, etc..... \$17, 340. 44

SUMMARY OF ENDOWMENTS

Invested endowment for general purposes..... \$1, 360, 904. 03
Invested endowment for specific purposes other than Freer endowment..... 1, 396, 223. 54

Total invested endowment other than Freer endowment... 2, 757, 127. 57
Freer invested endowment for specific purposes..... 5, 864, 061. 73

Total invested endowment for all purposes..... 8, 621, 189. 30

CLASSIFICATION OF INVESTMENTS

Deposited in the U. S. Treasury at 6 percent per annum, as authorized in the United States Revised Statutes, sec. 5591.... \$1, 000, 000. 00

Investments other than Freer endowment (cost or market value at date acquired):

Bonds (19 different groups)..... \$711, 260. 57
Stocks (43 different groups)..... 858, 132. 48
Real estate and first-mortgage notes..... 180, 296. 14
Uninvested capital..... 7, 438. 38

1, 757, 127. 57

Total investments other than Freer endowment..... 2, 757, 127. 57

Investment of Freer endowment (cost or market value at date acquired):

Bonds (36 different groups)..... 3, 039, 890. 60
Stocks (50 different groups)..... 2, 779, 031. 83
Real estate first-mortgage notes..... 4, 000. 00
Uninvested capital..... 41, 139. 30

5, 864, 061. 73

Total investments..... 8, 621, 189. 30

CASH BALANCES, RECEIPTS, AND DISBURSEMENTS DURING
FISCAL YEAR 1945¹

Cash balance on hand June 30, 1944----- \$719, 314. 48

Receipts:

Cash income from various sources for general work of the Institution-----	\$88, 398. 91	
Cash gifts and contributions expendable for special scientific objects (not for investment)-----	7, 343. 27	
Cash gifts for special scientific work (to be invested)-----	10, 150. 00	
Cash income from endowments for specific use other than Freer endowment and from miscellaneous sources (including refund of temporary advances)-----	154, 112. 47	
Cash capital from sale, call of securities, etc. (for investment)-----	362, 791. 36	
Total receipts other than Freer endowment-----		622, 796. 01
Cash income from Freer endowment-----	212, 552. 69	
Cash capital from sale, call of securities, etc. (for investment)-----	1, 425, 529. 25	
Total receipts from Freer endowment-----		1, 638, 081. 94
Total-----		2, 980, 192. 43

Disbursements:

From funds for general work of the Institution:		
Buildings—care, repairs, and alterations-----	3, 220. 00	
Furniture and fixtures-----	251. 98	
General administration-----	23, 721. 92	
Library-----	2, 832. 60	
Publications (comprising preparation, printing and distribution)-----	20, 964. 34	
Researches and explorations-----	17, 397. 14	
		68, 387. 98
From funds for specific use other than Freer endowment:		
Investments made from gifts and from savings on income-----	37, 313. 60	
Other expenditures, consisting largely of research work, travel, increase and care of special collections, etc., from income of endowment funds, and from cash gifts for specific use (including temporary advances)-----	121, 478. 77	
Reinvestment of cash capital from sale, call of securities, etc-----	349, 971. 04	
Cost of handling securities, fee of investment counsel, and accrued interest on bonds purchased-----	3, 781. 25	
		512, 544. 66

¹ This statement does not include Government appropriations under the administrative charge of the Institution.

Disbursements—Continued.

From Freer endowment:

Operating expenses of the gallery, salaries, field expenses, etc.....	\$58,013.42
Purchase of art objects.....	164,177.12
Reinvestment of cash capital from sale, call of securities, etc.....	1,390,671.18
Cost of handling securities, fee of invest- ment counsel, and accrued interest on bonds purchased.....	26,179.98
	\$1,639,041.70
Cash balance June 30, 1945.....	760,218.09
Total.....	2,399,259.79

Included in the above receipts was cash received as royalties from sales of Smithsonian Scientific Series to the amount of \$26,564.20. This was distributed as follows:

Smithsonian Institution Endowment Fund.....	\$11,803.85
Smithsonian Institution Emergency Fund.....	2,950.96
Smithsonian Institution Unrestricted Fund, General.....	8,852.89
Salaries.....	2,956.50
	26,564.20

Included in the foregoing are expenditures for researches in pure science, publications, explorations, care, increase, and study of collections, etc., as follows:

Expended from general funds of the Institution:

Publications.....	\$20,964.34
Researches and explorations.....	17,397.14
	\$38,361.48

Expenditures from funds devoted to specific purposes:

Researches and explorations.....	24,939.07
Care, increase, and study of special collections.....	9,129.85
Publications.....	7,681.92
	41,750.84

Total.....	80,112.32
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The practice of depositing on time in local trust companies and banks such revenues as may be spared temporarily has been continued during the past year, and interest on these deposits has amounted to \$469.79.

The Institution gratefully acknowledges gifts or bequests from the following:

American Malacological Union, toward publication of bibliography and short biographical sketch of Dr. W. H. Dall.

Mr. Conrad Chapman, work on bamboo collections.

Office of Inter-American Affairs, for researches in anthropology of Colombia, by Dr. Gregorio Hernandez de Alba.

Miss Mary Jane Rathbun, memorial fund to Richard Rathbun.
 Viking Fund, for researches among the Iroquois Indians.

All payments are made by check, signed by the Secretary of the Institution on the Treasurer of the United States, and all revenues are deposited to the credit of the same account. In many instances deposits are placed in bank for convenience of collection and later are withdrawn and deposited in the U. S. Treasury.

The foregoing report relates only to the private funds of the Institution.

The following annual appropriations were made by Congress for the Government bureaus under the administrative charge of the Smithsonian Institution for the fiscal year 1945:

Salaries and Expenses	\$1,224,090.00
National Zoological Park, D. C.	334,651.00
Cooperation with the American Republics (transfer from State Department)	67,432.00

The report of the audit of the Smithsonian private funds is given below:

SEPTEMBER 26, 1945.

EXECUTIVE COMMITTEE, BOARD OF REGENTS,
Smithsonian Institution, Washington, D. C.

SIRS: Pursuant to agreement we have audited the accounts of the Smithsonian Institution for the fiscal year ended June 30, 1945, and certify the balances of cash on hand, including Petty Cash Fund, June 30, 1945, to be \$762,118.09.

We have verified the records of receipts and disbursements maintained by the Institution and the agreement of the book balances with the bank balances.

We have examined all the securities in the custody of the Institution and in the custody of the banks and found them to agree with the book records.

We have compared the stated income of such securities with the receipts of records and found them in agreement therewith.

We have examined all vouchers covering disbursements for account of the Institution during the fiscal year ended June 30, 1945, together with the authority therefor, and have compared them with the Institution's record of expenditures and found them to agree.

We have examined and verified the accounts of the Institution with each trust fund.

We found the books of account and records well and accurately kept and the securities conveniently filed and securely cared for.

All information requested by your auditors was promptly and courteously furnished.

We certify the Balance Sheet, in our opinion, correctly presents the financial condition of the Institution as at June 30, 1945.

Respectfully submitted.

WILLIAM L. YEAGER,
Certified Public Accountant.

Respectfully submitted.

FREDERIC A. DELANO,
 VANNEVAR BUSH,
 CLARENCE CANNON,
Executive Committee.

GENERAL APPENDIX
TO THE
SMITHSONIAN REPORT FOR 1945

ADVERTISEMENT

The object of the GENERAL APPENDIX to the Annual Report of the Smithsonian Institution is to furnish brief accounts of scientific discovery in particular directions; reports of investigations made by collaborators of the Institution; and memoirs of a general character or on special topics that are of interest or value to the numerous correspondents of the Institution.

It has been a prominent object of the Board of Regents of the Smithsonian Institution from a very early date to enrich the annual report required of them by law with memoirs illustrating the more remarkable and important developments in physical and biological discovery, as well as showing the general character of the operations of the Institution; and, during the greater part of its history, this purpose has been carried out largely by the publication of such papers as would possess an interest to all attracted by scientific progress.

In 1880, induced in part by the discontinuance of an annual summary of progress which for 30 years previously had been issued by well-known private publishing firms, the Secretary had a series of abstracts prepared by competent collaborators, showing concisely the prominent features of recent scientific progress in astronomy, geology, meteorology, physics, chemistry, mineralogy, botany, zoology, and anthropology. This latter plan was continued, though not altogether satisfactorily, down to and including the year 1888.

In the report for 1889 a return was made to the earlier method of presenting a miscellaneous selection of papers (some of them original) embracing a considerable range of scientific investigation and discussion. This method has been continued in the present report for 1945.

OUR REVOLVING "ISLAND UNIVERSE" AND ITS SPIRALING COUNTERPARTS ¹

By WILLIAM T. SKILLING

Professor of Astronomy, retired, San Diego State College, San Diego, Calif.

[With 2 plates]

Our earth is an infinitesimal part of a great whirlpool of stars called the galaxy, or Milky Way. Not only are the sun, moon, and planets of the solar system moving as a very small unit that drifts with the rotation of the galaxy, but all the visible constellations of the sky are so close to us that they, too, are our fellow travelers in one small part of this cosmic eddy. Only recently has the tremendous velocity of our galactic rotation been measured and found to be 170 miles a second, in the direction of the constellation Cygnus.

On account of the smoothness of our travel and the freedom from any sharp turns in our course we do not feel this motion any more than we do the lesser speed of the revolution of the earth about the sun at a mere $18\frac{1}{2}$ miles a second. It is not the motion but abrupt changes in motion that we feel when riding in an automobile or train, and the earth makes no such changes in speed. The curve that the earth follows in its motion about the sun, 93,000,000 miles away, is so gradual that in each second the earth departs only one-ninth of an inch from a straight line while going forward $18\frac{1}{2}$ miles. Only by observing other moving bodies and the so-called fixed stars are we able to measure or even perceive our annual motion, and it is little wonder that astronomers have been slow in observing the vaster sweep of the whole solar system and its relatively near neighbors around a center that is 2 billion times as far away as the sun.

Soon after the beginning of this century the great Dutch astronomer Kapteyn, as a result of his studies in his native Holland, announced the discovery of two "star streams" flowing in particular directions. It has long been known that stars have some motion with respect to one another. But this previously known star motion, including that of the sun, was looked upon as being wholly at random. Kapteyn

¹ Reprinted by permission from the *Scientific Monthly*, vol. 60, No. 2, February 1945.

was the first to show any systematic drifts of great numbers of stars in any particular direction.

Gustaf Strömberg, at the Mount Wilson Observatory, examined the motions of various classes of stars and uncovered some surprising facts. His analysis of the motions of certain stars that the spectroscope showed to have very high velocities, 50 miles a second and up, proved that their directions are by no means at random. They seem to be leaving a particular part of the sky because the sun and its planets are moving toward that region.

The most rapidly moving stars, Strömberg found, are those far-distant groups, each consisting of many thousands of closely associated stars, which are called globular clusters. There are about a hundred of these clusters.

Thus, these and other men were finding beads of knowledge that eventually had to be strung together to show their relationship. The first to do this was Bertil Lindblad, of the Swedish observatory at Stockholm. He explained the apparent motion of high-velocity stars by fitting them into a theory of galactic rotation. He showed that if we assume the whole Milky Way system of stars to be revolving, then what otherwise appear to be peculiar and unaccountable motions of stars become natural consequences of that revolution. He likened our system of a billion or more stars to the spiral nebulae that can be seen far beyond the limits of the Milky Way and suggested that each of these nebulae is itself a distant island galaxy, seen as a blur of light because we are unable to distinguish any but the brightest individuals among its millions or billions of component stars.

Lindblad's suggestion was not new, but he was the first to form a complete theory. As far back as the time of Sir William Herschel our system of stars was being likened to the spiral nebulae. Herschel, with the large telescope that his patron George III had enabled him to build, could see many hazy patches of light that he shrewdly guessed might be star systems. The name "island universes," applied to these suppositional galaxies, became common at that time.

Herschel's telescopes were not powerful enough to resolve these nebulous objects into separate stars, but he predicted that all such clouds might one day be shown to consist of stars. With his largest telescope he had already proved that some objects which his smaller instruments showed only as glowing spots were really star clusters. What could be more natural than that with means more abundant, even, than those supplied by King George, telescopes might be made that would break up into stars even the most distant spots on the sky?

This very reasonable guess of Herschel's has since been found to be partly at fault, for the spectroscope, of more modern times, shows indisputably that some of the nebulae are gaseous and that some are

made of gas and dust clouds mixed. But both the spectroscope and the modern telescope give evidence that many others are, as Herschel suspected, composed of stars. In addition, more recent knowledge of their distances shows that gaseous nebulae or those composed of illuminated dust clouds are within our own stellar system whereas those that are composed of stars are outside of that system. Hubble calls them "extragalactic nebulae" to distinguish them from true nebulae. Shapley, of the Harvard College Observatory, calls them simply "galaxies." This word indicates their likeness to the stellar system but does not distinguish them from it as the prefix "extra" does.

The name by which these outside galaxies are popularly known is "spiral nebulae." Both parts of this name are in error for some do not have the spiral form and none of them are mere clouds, which "nebulae" implies. Nevertheless, a spiral form is the most striking characteristic of those that do possess it. The name "island universes," pretty well suggests their nature, but it violates the usual meaning of the word "universe." Thus all names of these outside star systems seem to be open to criticism.

But what evidence exists to support Lindblad's theory that our galaxy is one of these spiral nebulae? First, there is the evidence deduced from their distances.

The spiral nebulae lie at such great distances that the surveyor's parallax method used for nearer stars fails utterly to give any idea of their location. However, their distances had to be known, at least approximately, before it could be definitely decided whether they are separate systems beyond our stars or only outlying parts of our galaxy. Happily an exceedingly powerful indirect means of measurement was discovered by which Hubble, of the Mount Wilson Observatory, learned that the distance to a spiral in the constellation Triangulum is about three-quarters of a million light years. Another still more conspicuous one in Andromeda was found to be at practically the same distance.

The method employed by Hubble makes use of a certain kind of star known as a Cepheid variable, a number of which had been discovered in the spirals. These stars are exceptionally bright intrinsically and can be seen at a great distance. As far away as these variable stars can be clearly seen their distances can be calculated, for their period of change from maximum brightness to maximum again is a key to their real brightness, and this, in turn, is a key to their distance.

A curve can be drawn (from table 1, for example) showing the relation between period and brightness, and from the curve the actual luminosity of a star of any period can be found. Then by simply comparing this real brightness with the brightness that the star seems to have, as measured with a photometer, the star's distance can be found.

(If there is obscuring matter between us and the star its dimming effect must be found and allowed for before the comparison of real and apparent brightness is made.)

TABLE 1.—*Brightness of Cepheid variables of different periods*

Period in days:	Number of times brighter than sun
2½	350
5	550
10	830
20	1,500
40	2,500

The two nearest of the spiral nebulae were in this way found to be so distant as to be well separated from the outermost stars of our galaxy. The estimated distance from side to side of the Milky Way system is about 100,000 light years. Seven or eight such systems could be laid side by side in empty space between our stars and those of the great nebula in Andromeda, one of our two nearest neighbors, before the gap would be bridged.

A second point of similarity between our galaxy and the spiral nebulae is size. The sizes of extragalactic nebulae, as found from their angular diameters and distances, approach nearly enough the size of the stellar system to warrant their being classed with it rather than with even the largest of our own star clusters or star clouds, such as are seen along the Milky Way.

Third, the similarity of our star system and the spiral nebulae is shown in the flattened shape of each (plate 1). Herschel, with unlimited patience, counted stars in all directions and found that the stellar system is "shaped like a grindstone," to use his own comparison. More recent counts amplify Herschel's discovery by showing that the sun and the solar system are not centrally situated in our galaxy. To the naked eye or with a small telescope there seem to be about as many stars in one direction as in another in the plane of the Milky Way, but with a telescope that will penetrate to greater depths many more stars can be seen in the direction of Sagittarius than in that of Auriga. The reason is that we are far out from the center in Sagittarius toward the "anticenter" (the point opposite the center) near Auriga. Measurements of a different kind place us about two-thirds of the way from the center of the circumference. But still we are nearly in the plane of the Milky Way.

Finally, the motion of our galaxy is similar to the motion of the spiral nebulae. It is now definitely known that the spirals are rotating. For this belief is there not strong presumptive evidence in the appearance of the spiral nebulae? There seems little doubt that they have acquired their flattened pinwheel appearance (plate 2) from rotation about a center, for a group of stars would in time collapse to their common center if it were not for the centrifugal effect of motion

that counterbalances the inward pull of gravitation. If this appearance were not sufficient proof of the rotation of the spirals, there are spectroscopic observations to show it. V. M. Slipher, at the Flagstaff Observatory, and more recently Dr. Hubble, at the Mount Wilson Observatory, have used the spectroscope upon nebulae in much the same way it is used in measuring the velocity of rotation of a planet. Using spiral nebulae that do not have their flat side directly toward us, the slit of the instrument was set as nearly as could be upon the equator of the spiral, perpendicular to the axis of rotation. The resulting spectral lines slant because of the approach of one side of the light source and the recession of the other side. Slipher and Hubble agree that there is motion in the direction we should expect; most of the material of the nebula is at the more condensed central part, and as this turns, the two arms projecting from its opposite sides are left trailing behind.

At our great distance from the spirals the angular motion is too slow to be observed with certainty on direct photographs of the nebulae, even with pictures taken several years apart. Perhaps photographs of the next century when compared with those taken by this generation of astronomers may show changes in the position of stars of these galaxies.

There can be no question as to the rotation of spiral nebulae; what, then, is the evidence that our system of stars is like them? Some of the extragalactic nebulae that are not spiral show no sign of motion. If our galaxy turns, how would the motion of its stars be observed to show whether or not they are revolving about a common center? Lindblad was unable to make any direct measurement of our galactic rotation. The position of the earth within the galaxy is an unfavorable one for observation of its rotation. So Lindblad's approach to the problem was to explain, insofar as possible, all observed motions of the stars of the galaxy (as they appear to move with reference to our sun) in terms of a great rotation.

Lindblad interpreted the apparent motion of the so-called high-velocity stars as being caused by our more rapid rate as we and they revolve, all in the same direction, around the center of the stellar system. These slow "high-velocity stars" seem to be headed backward with respect to the true direction of all the stars. They seem rapid because they lag behind so rapidly.

But why would not stars equally distant from the center of the galaxy all move equally fast? For comparison, it is well known that a comet travels very slowly while going around the end of its long elliptical orbit that is farthest from the sun. Then it gains great speed through years spent in falling closer. Halley's comet, for example, went about 35 times as fast in 1910, when it was making the

quick swing around its "perihelion," as it is moving now, during the 1940 and 1950 decades, when it is out beyond the orbit of Neptune. As the comet falls back toward the sun it will regain its speed. Even the earth, which has an orbit nearly but not quite circular, goes faster in December than in June because it is then 3 percent nearer the central sun. It is partly due to this greater velocity of the earth that winters in the Northern Hemisphere are a week shorter than summers. If their orbits were exactly circular around the sun, all bodies at equal distances from it would go at the same velocity, whether they were planets, comets, baseballs, or grains of sand. Stars would behave in the same way in going around their attracting center.

In the great rotation of our galaxy most star orbits around the common center are nearly circular, and therefore any two stars fairly close together, say within a hundred light-years of each other, move at nearly the same velocity. The sun is a typical star and has a nearly circular orbit. The difference between the velocity the sun actually has and what it would have if its orbit were exactly circular is found by comparing its motion with the average for all stars in its vicinity. This variation from the average velocity is called solar motion. It is 12 miles a second, as was found by several observers. The variation of the rate of any star from the velocity it would have if its orbit were circular can be similarly found. These variations in the velocities of stars caused by differences in the shapes of their orbits are often spoken of as their "peculiar motions," to distinguish them from the variations in velocities caused by differences in distance from the center of the galaxy.

Although an occasional star is found to have a velocity with respect to the sun greater than 50 miles a second, it is never going in the direction of the sun's revolution around the galactic center. It is always a slow star that we are overtaking. No stars have been found that run as much faster than the sun as some of them run slower. The reason is that they would be thrown out of the galaxy by centrifugal effect if they did. Neighboring stars can go a little faster than the sun, but they cannot go much faster. If a star should pass us with a velocity as much as 30 or 40 miles a second greater than that of the sun, we could bid it farewell, for such a motion would carry it out of the stellar system beyond the gravitational control of the stars.

In this way the puzzling stream of "high-speed stars" was explained by Lindblad in simple terms of gravitation. They are really low-velocity stars at the slow end of eccentric orbits, and we, and other stars of fairly uniform speed, are overtaking and passing them. These eccentric stars will in time fall in toward the center, regaining speed, but now they are lagging badly behind.

And the extreme high speed of globular clusters of stars, as much as 170 miles a second, simply means that these clusters are not part of our galaxy at all, or at least do not rotate with it, and the observed velocity is really our own speed of travel with the galaxy as we go rapidly past the stationary clusters.

Soon after Lindblad's explanation of "high-velocity" stars and other phenomena of stellar motion, a Dutch astronomer, Oort, developed a direct method of studying the rotation of the galaxy by using the velocities of many stars at known distances from us. He worked out a comparatively simple means of using such measurements to learn

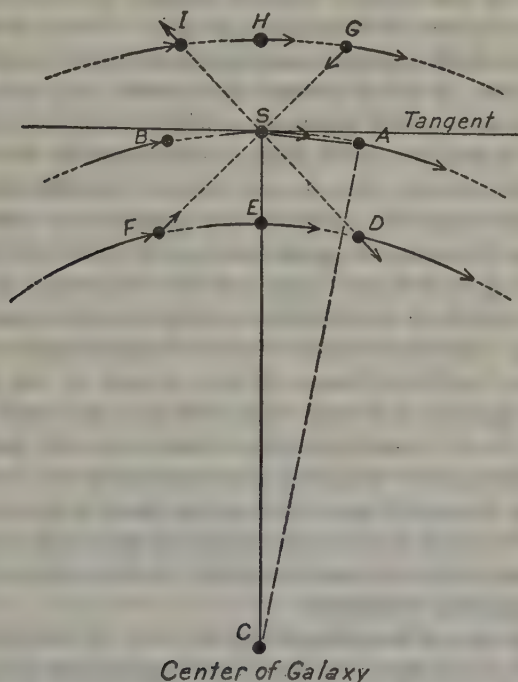


FIGURE 1.—Intragalactic velocities, showing relative velocities of sun (S) and stars around the galactic center. Short arrows represent components of motion of stars toward or from the sun, as shown by the stars' spectra.

a great deal about the stellar system and our position in it. His plan of procedure has been used since then by a number of astronomers, who have applied it to various classes of stars. Notwithstanding the great difficulty of making the required measurements the different workers have arrived at very similar results.

Oort's plan is based on the fact that revolving bodies controlled by a central attractive force move at unequal speeds depending on differences in distances from the center (fig. 1). The different velocities of planets revolving around the sun illustrate this. Pluto, the outermost planet known, travels at 3 miles a second; Jupiter, nearer

the sun, at 8.1 miles; the earth at 18.5; and Mercury, nearest the sun, has an average speed of nearly 30 miles a second.

Our solar system of sun and planets has practically all its mass at the center; 99% percent of it resides in the sun, only one-seventh of 1 percent in the planets. Being so constituted, the rate of motion of a planet at any known distance from the center is very simply calculated by means of Kepler's great discovery of more than 300 years ago, his law of "harmonic motion."

The rate of motion (and the period) of a star at any given distance from the center of the stellar system is not so easily found, for the mass of the system is more widely distributed. There is no great central star dominating all else. If the distribution of material in the stellar system were quite uniform throughout, with no concentration of stars toward the center, the whole flattened Milky Way system would rotate as a wheel, and we could detect no motion at all unless we could observe some outside landmarks, such as extragalactic nebulae, that do not revolve with the stars.

Actually, however, the stars of our galaxy are sufficiently concentrated near its center to give measurably different stellar velocities. Yet the galaxy is so large and the difference of velocity as seen from the earth so small that our greatest telescopes are needed to observe the relative motion; even with the largest telescopes we cannot observe individual stars of our system as far away as the center of the galaxy, and only with difficulty can star velocities be measured as far as one-fourth the distance to the galactic center. Since Oort's method of detecting and computing the rotation of the stellar system depended upon measuring their relative motion, his work had to be based upon observations of the most distant observable stars. But even these are relatively close in terms of the dimensions of the galactic whirlpool.

Because the closest stars that can be used in obtaining data for Oort's method had to be more than 1,000 light-years distant from us, Plaskett and Pearce of the Dominion Observatory, Victoria, B. C., worked with those very hot and white giants of classes O and B. Rigel, lying at the foot of Orion, is one of these and is one of our brightest-appearing stars, but being only about 500 light-years away is too close to be used in Oort's method. However, stars of this type can easily be seen at much greater distances with such a telescope as the one at Victoria.

Others have used those reddest of all stars, the N type, which average several hundred times the brightness of the sun. The so-called planetary nebulae are stars surrounded by gas, which makes them exceptionally luminous. The peculiar, brilliant gas, supposed to have been thrown out by some violent explosion long ago, can be seen at

astounding distances. But in some respects the best stars of all to show rotation of the galaxy are the Cepheid variables, the stars that gave distances to the spiral nebulae as mentioned above. Joy, at the Mount Wilson Observatory, has studied about 150 of these, distributed mainly along the Milky Way. The results thus obtained are very dependable because of the unusually reliable manner, explained above, in which their distances can be determined.

Motions of these stars could theoretically be measured in two ways: by getting the angular distance they travel across the sky in a certain length of time—their "cross motion"—or by finding the speed in miles a second by which they come closer to us or move farther away—"radial motion" or "motion in the line of sight." The spectroscope will measure this line-of-sight speed. The lines of the spectrum of an approaching or receding star are shifted a little toward the blue or the red end of the spectrum as a result of the motion. This is often called the Doppler shift. The greater the speed of the star the greater the shift.

Cross motion is not useful in studying galactic rotation, as many years must elapse between the taking of two photographs of the stars to show any appreciable change in their positions. But the spectrum of a star can be photographed in a few minutes (or hours, depending on its dimness) and the star's radial velocity is found immediately.

The general principle of Oort's method may be readily understood by considering the solar system. A planet, such as Venus, when nearest the earth and directly between us and the sun has cross motion because it goes faster than the earth, but it has no radial motion that would be indicated by the spectroscope because it is keeping parallel to the earth's orbit and so is not changing its distance from the earth. Likewise Mars when nearest the earth on the opposite side from the sun is not changing its radial distance, although it has cross motion because it moves slower than the earth.

If we assume another planet a little in advance of the earth, or behind it, in the same orbit, the hypothetical planet would show no radial motion. The spectroscope would show it as a stationary object. But in all other directions except these four—toward the center, away from the center, straight ahead, or straight behind—planets would appear to be coming closer to us or getting farther away from us, and the spectroscope could measure this speed of approach or recession.

So it is with the stars. Those directly ahead of us or behind us in our revolution about a common galactic center, and those toward the center and away from the center, show no motion in the line of sight to be measured by the spectroscope. (This would be true

except for the special motions already mentioned, usually slight, for which correction can be made.) All other stars—all that are not in these four directions—both those farther from the center of the system than we are and those closer to it, have more or less apparent motion in the line of sight. Those having the greatest motion are the stars halfway between the points of no motion. Therefore, at 45° along the Milky Way to each side of the center of the stellar system and at 45° each side of the anticenter maximum radial motion is indicated by the spectroscope.

Hence, spectroscopic measurements of radial velocities of stars along the Milky Way will show where the center is, around which the stars revolve. It must be at one of the points of zero radial velocity, and halfway between two points of maximum velocity. It is found to be in the Milky Way in the direction of the great star clouds of Sagittarius and Scorpio. The anticenter (180° from the center) is in the Milky Way where the constellations of Taurus, Auriga, and Gemini meet. A third point of interest is the one toward which the solar system is moving. It is in the Milky Way also, and naturally is at right angles to the line leading to the center. It is located in Cygnus, near the star Deneb.

The distance to the center, as well as the direction to it, can be found from the star velocities given by the spectroscope. The principle upon which this is done may be briefly stated. A star at the same distance as the sun from their common center of revolution would, if fairly near the sun, be almost in the tangent to the sun's orbit (that is, 90° from their common center). But if the star is 6 or 8 thousand light-years ahead of the sun, it would have turned in toward the center several degrees from the tangent at the sun. At 1,000 light-years distance it would be seen about 1° off the tangent, or 89° from the center instead of 90° . Cepheid variables were measured out to a distance of about 8,000 light-years from the sun. The direction to a star at that distance with no radial motion is not quite the same as the direction to a closer star with no radial motion. There is a measurable angle which gives the curvature of the sun's orbit. (See fig. 1.) Joy's result with Cepheids and the results of others using different classes of stars agree very well in giving about 33,000 light-years as the distance of the solar system from the galactic center in Sagittarius.

The diameter of the whole stellar system has been estimated at about 100,000 light-years; hence our place in the system is about two-thirds of the way out from the center toward the edge of the Milky Way, in the direction of the constellation Auriga and away from the constellation Sagittarius.

Another interesting value growing out of these spectroscopic measurements is the velocity of sun and stars around the great central nucleus of star clouds.

The result actually given by the star's spectrum is the component of velocity directed toward or away from the observer. (See fig. 1.) The maximum value of this line-of-sight velocity is called Oort's constant because it figures so prominently in the method devised by Oort for studying galactic rotation. It is a constant quantity for any given difference in distance to stars along the Milky Way: for each additional 1,000 light-years in any of the four directions of maximum radial motion, the radial motion increases about $3\frac{1}{2}$ miles a second. Thus, for a star at 8,000 light-years from us the spectroscope should show a velocity of about 28 miles a second. Using the well-known laws of gravitation, this value can be related to the speed of rotation of the galaxy. Oort worked out an equation in which his "constant" would be one of the known terms, the distance to the center another known term, and the velocity of the sun the unknown term to be found.

Based upon the above principles various observers have arrived at somewhere near 170 miles a second as the velocity of the sun and its planets in their revolution around the center. Most of the stars that are near enough to be visible to the naked eye move at about the same speed, and that is why a great telescope is needed to study the revolution of the galaxy.

Knowing the velocity of the sun and its distance from the center it is a mere matter of arithmetic to find its period of revolution around the center. The radius of the orbit is 33,000 light-years, each light-year being nearly 6 trillion miles. The period found proves to be in the neighborhood of 200 million years.

Geologists place the age of the earth at around 2,000 million years, basing their estimate on the chemical analysis of rocks containing the radioactive element uranium and a peculiar kind of lead into which it very slowly changes at a known rate. The relative amounts of the two metals show when the rock was formed. From these figures it would seem that the sun and earth have had time for only about 10 revolutions around the distant center of the stellar system since the earth was formed and solidified.

Slow and difficult as it has been to work out and prove this theory of galactic rotation, the theory simplifies astronomy by relating to one another various puzzling facts about motion that are hard to understand one by one. Such matters as "star streaming," "asymmetry of motion," and "high- and low-velocity stars," are more easily explained together than separately. In this respect the rotation theory has, in a measure, paralleled the heliocentric theory of the solar system by which Copernicus explained such riddles as "retrograde motion" of planets.



THE SPIRAL NEBULA H V 19 IN ANDROMEDA.

Doubtless our galaxy would resemble this nebula if seen edge-on from a great distance. The dark central line is caused by dust in the plane of the nebula and corresponds to the dark rifts in our Milky Way. The individual stars are in the foreground—within our galaxy. (Courtesy of the Mount Wilson Observatory.)



THE SPIRAL NEBULA M 33 IN TRIANGULUM.

Our galaxy would probably resemble this nebula if we could see it from the outside nearly flat side-on. Its plane is tilted 33° to the line of sight, and so it has been possible for astronomers to measure with the spectroscope the rotational speed of many of its points of condensation. The nebula rotates as if it were a solid from the center halfway out to the edge, after which speed falls off. Its maximum speed of turning is about 75 miles a second, and the whole nebula approaches us at about 100 miles a second. Direction of rotation is clockwise. (Courtesy of the Mount Wilson Observatory.)

MEDICAL USES OF THE CYCLOTRON¹

By F. G. SPEAR, M. A., M. D., D. M. R. E.

Strangeways Research Laboratory, Cambridge, England
Member Scientific Staff, Medical Research Council

[With 4 plates]

The idea of transmutation seems to have arisen among the Alexandrian Greeks in the early centuries of our era, and to have been transmitted to western Europe by the Arabs. The alchemy of the Middle Ages was something more than the pretended art of turning base metals into gold by the philosopher's stone: it was a phase in the development of systematic chemistry. In the sixteenth century Paracelsus gave it a new direction by declaring that its true object was not the making of gold but the preparation of medicines, and this led to increasing attention being paid to the investigation of the properties of substances and of their effects on the human body (1).²

It was not, however, until 1896 that the dream of the alchemists was realized with the discovery of the "natural" radioactivity of uranium by Becquerel (2), when the first genuine transmutation was recognized. Within two years Madame Curie discovered radium, with a radioactivity (in the pure state) several million times that of uranium (3). This "gave an impetus to the systematic chemical examination of uranium minerals and soon led to the detection of several new radioactive bodies" (4). Almost as soon as they were discovered their effects on the human body were studied, and the consequence to physics, medicine, and later to industry of the discovery of radioactivity has been immense, but the distribution of the radioactive material has been much influenced by international conditions during the (nearly) 50 years since radium was discovered. Half the world's supply of radium at the time of the last war was taken by industry, and its value rose to 100,000 times that of gold (5). This philosopher's stone, presented

¹ Based on a paper read on April 29, 1944, before the Midland Branch of the Institute of Physics at Birmingham. Reprinted by permission from the *Journal of Scientific Instruments*, vol. 22, No. 2, February 1945.

² Numbers in parentheses refer to bibliography at end of paper.

to the world for nothing by the Curies (6), was now selling at a very high price.

But away from the distractions of the world of industry the first successful "artificial" disintegration of ordinary chemical elements was made by Rutherford in 1919 at Cambridge by passing alpha particles through nitrogen which produced scintillations on a screen when the absorbing matter present was greater than that which corresponded to the ordinary range of alpha particles (4). Rutherford concluded that the scintillations were due to particles ejected with great speed from the nitrogen nucleus by impact of an alpha particle, and suggested that these particles were hydrogen nuclei or protons. Evidence of the capture of an alpha particle by the nucleus of the nitrogen atom was obtained by Blackett (7) a few years later by photographing alpha-ray tracks in a Wilson expansion chamber. In 1934, Joliot and Curie (daughter of Madame Curie) gave the first chemical proof of artificial transmutation and of the capture of the alpha particle (8).

The alpha particle, with its two positive charges, has twice the potential barrier to surmount in order to penetrate an atomic nucleus as a single charged particle, and consequently search was made for a means of accelerating hydrogen nuclei or protons carrying a single positive charge. Most investigators used high voltages for the purpose, but among those interested in the subject was E. O. Lawrence, born 2 years after the discovery of radium, who saw a paper by the German physicist, Wideroe, describing a method for energizing ionized particles by hollow cylindrical electrodes in a tandem pair, each electrode being connected to the leg of an oscillating high-frequency circuit. Lawrence conceived the idea of raising the efficiency of the system, without increasing the length of the apparatus to unmanageable proportions, by giving the particles a circular motion by employing a powerful magnetic field within which a hollow electrode was fixed.³ A design for "a magnetic resonance accelerator for ions" was made, and a model of the apparatus tried out. It worked, and was given the nickname of "cyclotron" (9). With a linear accelerator and an oscillating current of 40 kv., 30 tandem electrodes would be required to achieve an ion energy of 1.2 mev.; 150 revolutions in the cyclotron with an oscillating current of only 4 kv., however, produces ions of equal energy (10). The result has been a succession of cyclotrons (see table 1) built at the University of California, Berkeley, by a team which were said "not to know the meaning of a regulated existence . . . as day and night the work went on" (10).

³ A single hollow D-electrode was used in the early apparatus; later a pair of D-shaped electrodes, now a characteristic feature of cyclotron design, were used.

TABLE 1.—*The Berkeley cyclotrons*

	1	2		3	4
		a	b		
Date (begun)-----	1929	1932	1936	1939	1940
Housing-----	Physics laboratory	Radiation laboratory	Crocker laboratory	Distant hilltop	
Magnet (tons)-----	1	80	190	4,000	
Pole diameter (inches)-----	11	27	37	60	184
Energy of particles (mev.)-----	1.25	4	8	16	100
Beam in air (feet)-----			1	5	140
Water protection (feet)-----				5	25

¹ 45 inches available.² 72 inches available.³ For deuterons; 21 for neutrons.⁴ Conjectural, apparatus under construction.

Each apparatus was bigger than its predecessor and capable of producing greater quantities of radioactive material (pl. 1, fig. 1). In 1 day (1940) as much radio sodium, as measured by gamma-ray activity, could be made as would correspond with 100 mg. of radium. For an initial cost of some £10,000 (prewar of course) and with annual running costs of, say, £2,000, a cyclotron could yield energies of 8 million electron-volts or the energy equivalent of gamma radiation from 100,000 g. of radium (11). But while the cost was trivial compared with that of radium, the size of the apparatus was becoming considerable and much additional space was required for the devices necessary to protect those who came near the machine at work. When one looks at a cloud-chamber photograph (pl. 1, fig. 2) "and realizes that it represents the ionization which occurs in a layer of one's body about a thousandth of an inch thick every one-hundredth of a second, the amount of ionization present in the body of anyone standing near the cyclotron becomes impressive" (12). Stage by stage the technical difficulties of these huge machines were surmounted, and the scientific investigations begun. A study of the properties of artificial radioactive substances is now proceeding apace, and alongside this, work has begun on their effects on the human body.⁴ This paper is concerned with the constructive applications of the new discovery to medicine and the way in which the cyclotron can be used in "the preparation of medicines."

Not long before the United States entered the war, the designer of the cyclotron was described to an American audience in these words: "Lawrence and his collaborators are providing medicine, biology, and physics with agents that should revolutionize our knowledge of the structure of the world and everything that lives in it" (13). The

⁴ This work is being directed by Lawrence's medical brother (J. H. Lawrence) at the Crocker laboratory, built, equipped and staffed for the sole purpose of studying and developing the biological applications of the cyclotron (No. 3 of table 1) housed in the building (10).

harnessing of atomic energy resulting from the artificial disintegration or transmutation of elements could indeed transform the world in a manner beyond the dreams of the old alchemists. Against the background of world war and the sinister possibilities that can be conjured up, it is to be hoped that the future results of "atom smashing" will not be merely destructive but rather for greater social integration and the increased welfare of mankind (14).

THE CYCLOTRON AS A MEDICAL INSTRUMENT

The physics of the cyclotron have been described in other papers in this Journal and elsewhere (9, 15). It was first designed for use in the domain of atomic physics, but it has provided medicine and biology with two new tools for research, viz, a beam of very penetrating uncharged particles or neutrons⁵ and an array of artificially radioactive substances which can be used in two different ways. They can be administered in quantities so small that their presence can be detected only by sensitive physical apparatus, and in this high dilution no biological effects of the substance can be observed with the means at present available. The progress of the radioactive atom through the organs of plant, animal, or man can, however, be followed by physical detectors, and yields information otherwise unobtainable. Illustrations of the use of these "tagged atoms" or tracers in biological and clinical research will be given later.

In larger quantity, radioactive substances can be administered so that the radiation they emit is used in some localized region of the body to produce definite biological changes—usually destructive ones such as the elimination of unwanted cells. The problem in this case is to localize the radioactive substance in the particular region required. This is not always so difficult as it might seem at first sight. Selective absorption of certain substances in particular organs has been familiar for a long time. And since virtually all the known elements can now be made artificially radioactive, it is possible to select the most suitable element for the purpose required and then proceed to make a radioactive compound in the composition of which it is included. The length of life of the artificial product is the limiting factor and that cannot be predetermined. This therapeutic administration of radioactive substances is a more difficult field of research than metabolic studies with tracer substances, and progress must of necessity be slower and less spectacular. But already it is possible in certain instances (see later) to achieve as much by the internal administration of a radioactive element in

⁵ The cyclotron is the most efficient but not, of course, the only means by which neutrons can be produced.

the patient's own home as could previously be done by a series of exposures to X-radiation which is a much more exhausting experience for the patient and requires either in-patient accommodation or at least frequent visits to the clinic or hospital. Radioactive elements prepared by the Berkeley cyclotron are distributed (usually by airplane) to various parts of America for use in hospitals and laboratories. In 1942 there were 13 cyclotrons in the United States and 9 planned or in building. There were 10 in other countries, including 3 in England.

The neutron beam provided by the cyclotron is thousands of times more powerful than any other method at present can furnish. Neutrons ionize in a different manner from that of gamma- or X-rays, and, since ionization and biological action are linked, the biological action of neutrons on normal and diseased tissues constitutes a new and wide field of research.

These three uses of the cyclotron in biological research will now be considered in greater detail.

TAGGED ATOMS IN TRACER SUBSTANCES

Radioactive or tagged atoms are used to enable the investigator to see where the rest of his material is going—in just the same manner as tracer bullets are used in antiaircraft or other gunfire (16).

The method was used first by Hevesy (17) in 1923 when he employed radium D as a tracer for its isotope lead, and later radium E for bismuth in his studies on plant metabolism. These substances are not, however, those normally used by plants, and were admittedly foreign substances introduced into the plant's economy for experimental purposes. The great advantage of the artificially produced radioactivity is that substances can be selected which are natural to the plant's metabolism. One radioactive atom in a million is sufficient for the progress of the substance to be followed with extreme accuracy by physical detectors and at this dilution no biological effects of the radioactivity can be detected. By "tagging" atoms of a substance natural to the plant or animal under observation it is possible to discriminate between the added compound and similar compounds already present in the system. This is a conspicuous advantage over ordinary methods of chemical and biochemical analysis where added substances are indistinguishable from those already present.

It is possible to make radioactive isotopes of all the stable elements, and these isotopes behave identically with the commonly obtained element both chemically and physiologically. The two differ only in the fact that the artificial product is physically detectable by its radioactivity in whatever chemical reactions it takes part. A list of some of the more commonly used radioactive elements is given in table 2 (18).

TABLE 2.—List of radioactive elements which are being used in biological and medical investigations

[See ref. 18]		
Radioactive element:	Type of radiation	Half-life
$^1\text{H}^3$	B—	30.0 years.
$^{11}\text{C}^{11}$	B+	21.0 minutes.
$^{14}\text{C}^{14}$	B—	1,000.0 years.
$^{13}\text{N}^{13}$	B+, γ	9.93 minutes.
$^{23}\text{Na}^{23}$	B+	3.0 years.
$^{24}\text{Na}^{24}$	B—, γ	14.8 hours.
$^{27}\text{Mg}^{27}$	B—, γ	10.2 minutes.
$^{32}\text{P}^{32}$	B—	14.3 days.
$^{35}\text{S}^{35}$	B—	88.0 days.
$^{38}\text{Cl}^{38}$	B—, γ	37.0 minutes.
$^{42}\text{K}^{42}$	B—, γ	12.4 hours.
$^{45}\text{Ca}^{45}$	B—, γ	180.0 days.
$^{54}\text{Mn}^{54}$	K, γ	310.0 days.
$^{59}\text{Fe}^{59}$	B—, γ	47.0 days.
$^{60}\text{Co}^{60}$	K, γ , e^- , B+	270.0 days.
$^{64}\text{Cu}^{64}$	B—, B+, K	12.8 hours.
$^{65}\text{Zn}^{65}$	B+, k , γ , e^-	250.0 days.
$^{76}\text{As}^{76}$	B—, B+, K, γ	26.8 hours.
$^{74}\text{As}^{74}$	B—, B+, γ	16.0 days.
$^{82}\text{Br}^{82}$	B—, γ	34.0 hours.
$^{86, 88}\text{Rb}^{86, 88}$	B—	18.0 days.
$^{89}\text{Sr}^{89}$	B—	55.0 days.
$^{124}\text{I}^{124}$	B—, γ	8.0 days.
$^{211}\text{At}^{211}$	K, α	7.5 hours.

Tracer substances have proved of great value in studying metabolic process in plants and animals, but it must not be supposed that their introduction has supplanted ordinary chemical methods which still have a recognized place and use. A new tool is not necessarily the best for all purposes.

An ingenious device is used at Berkeley for the preparation of radioactive substances simultaneously with the production of neutrons for other purposes. The substance to be activated, e. g., red phosphorus, is introduced into the vacuum chamber of the cyclotron on probes so arranged as not to interfere with the bombardment of the beryllium target and the emission of neutrons from the target chamber (19). The cyclotron vacuum has, however, to be broken when the probes are inserted or withdrawn at intervals of several days.

Various methods are used for the detection of tracer substances:

(a) *Measurement of uptake*.—An animal is fed with a radioactive substance and after a given time is sacrificed. An assessment is then made of the radioactivity of any or all the organs of its body. The process is repeated with other animals of the same species killed after different intervals. The assessments of radioactive material are then plotted against time on a graph, the quantity of material being given as a percentage of substance originally administered found per gram of tissue examined. It is, of course, not necessary to use the whole organ in every case; a weighed portion may be used instead, and in

some cases a piece can be taken from the animal under anesthesia without killing it.

(b) *Autophotography*.—The tracer substance is administered and after the predetermined time the animal is killed or a portion of an organ removed (biopsy) under anesthesia. The tissue is sectioned as for microscopic purposes and some of the sections are stained with colored dyes and others placed upon photographic plates. The areas of fogging, which correspond to radioactive deposits, are compared with the almost identical stained preparations and the distribution of the tracer substance studied qualitatively. In this method the sections used for fogging plates are impregnated in the final stage of preparation with collodion in place of the paraffin customarily used in histological work. For large organs, such as one of the long bones, the autophotograph can be compared with an X-ray picture of the same part (e. g., see pl. 3, fig. 2). Very thin substances—the leaf of a plant, for example—do not need to be sectioned on a microtome but can be placed direct upon the photographic plate (pl. 2, fig 1). The fogging of the plate is due to the emission of the beta rays from the tracer substance, and the best photographic results are obtained when something like 2×10^6 beta particles per sq. cm. strike the film during the exposure period.

(c) *Geiger counter*.—A method involving the sacrifice of the subject under examination is obviously not applicable to hospital practice!

For the detection of tracer substances in human subjects a preparation is chosen which emits gamma radiation (e. g., radio iodine). After administration, a Geiger counter, placed on the surface of the body (16, 20) over the organ to be investigated, records the radioactivity due to tracer present (pl. 2, fig. 2). Radio iodine is made by the deuteron bombardment of metallic tellurium, and has a half-life of 8 days. It emits both beta and gamma rays.

(d) *Double tag*.—An ingenious modification of the autophotographic method is occasionally used. By using the unstable H^3 in the preparation of the dyes for staining it is possible to combine color change and radioactivity in the same preparation.

By such methods it has been possible to show the selective absorption of various activated substances in particular tissues; a variation in absorption in different states of activity of living tissues due either to normal circumstances in health or abnormal conditions imposed by disease; and even a variation in different parts of the same cell (21) which can be examined after disintegration of a mass of cells by the ultracentrifuge which separates the central and heavier nuclear material from the surrounding and lighter cytoplasm.

The amount of tracer substance taken up depends on the total content of the same (inactive or natural) elements in the tissue at the time

of administration of the tracer element, the rate of turn-over of the material in the organ concerned, and whether or not new tissues are being laid down, i. e., active cell multiplication, is going on at the time.

Radio sodium, an emitter of gamma rays, given to a patient by the mouth as common salt, can be detected by means of a Gieger counter within 2 minutes of administration, in the fingertips. The element $^{24}_{11}\text{Na}$ has a very short half-life of 14.8 hours, and less than 10 percent is eliminated from the body within the period of measurable activity.⁶ It is excreted by the urine and sweat glands.

Radio iron fed to cows appears in the milk within 24 hours. It is taken up selectively by the red corpuscles of the blood and by bone marrow, and in anemic animals the uptake is over 50 times that of normal animals. Its absorption depends on the organism's need for iron and it is best administered in a series of small doses as the percentage uptake is greater under these conditions. It used to be thought that the iron content of the body was regulated by excretion, but observation with radio iron has shown that just as much iron is excreted by anemic dogs as by healthy ones.

Radio iodine is taken up rapidly and in large quantity by the thyroid gland, which absorbs 5,000 times as much as other tissues. The concentration of radio iodine (β - and γ -ray emitter) can be raised in animals to a level which leads to the complete destruction of the gland, yet the action is so localized that the adjacent parathyroid gland is unaffected (pl. 3, fig. 1). The activity of the unhealthy thyroid gland varies markedly according to the nature of the disease affecting it. In a state of overactivity (hyperthyroidism) the uptake of radio iodine is rapid, and this is followed by a rapid loss of the element. Loss of glandular activity is reflected in a very small uptake of iodine. It is possible to classify different types of disease of the gland by the radio-iodine uptake. In malignant disease of the thyroid its cells, unfortunately, lose their capacity to take up iodine, so that it is unlikely that cancer of this gland can be treated by the administration of radio iodine.

Radio carbon has been used in the study of plant metabolism and quite revolutionary discoveries have been made, especially as regards the capacity of plants to reduce carbon dioxide. Others besides the chlorophyll-producing plants can reduce carbon dioxide, and the latter, contrary to general belief, are able to do so in complete darkness though the activity is less than one-twentieth of that in sunlight. It takes 100 minutes for radio carbon to be built up into the plant solids. Barley can synthesize sugar from radio carbon in 2

⁶ In designating a specific isotope of an element, the total mass is written as a superscription on the right of the chemical symbol and the atomic number as a subscription on the left.

hours. Perhaps the neatest way to manufacture "tagged" sugar, since chemical synthesis of sugar is a difficult process, is by the action of bacteria in reducing carbon dioxide made with radio carbon.

Radio calcium and *radio strontium* are taken up selectively by bone, especially in regions where active growth is taking place. Radio strontium, with a half-life of 55 days, is preferable to radio calcium whose half-life is 180 days and cannot be prepared in the same high concentration as radio strontium. The two elements belong to the same group of the periodic table and have similar chemical and physiological properties. A striking illustration of the deposition of radio strontium in growing bone is shown in plate 3, figure 2. Five hundred millicuries of the element were given to a child 2 days before amputation of the leg for a cancerous growth. An autophotograph of a longitudinal section of the leg, compared with an X-ray photograph on the same scale, shows the deposition of the radioactive element in the tumor cells (malignant growth) and in the epiphysial line (normal bone growth).

Radio phosphorus is taken up by bone, bone marrow, spleen, lymph nodes, and liver as well as by certain cancerous growths (sarcomata). Its use in the treatment of blood diseases is described in the next section.

Tracer substances are also being used to study the metabolism of insects and in some interesting studies in comparative morphology. Organs supposed to be homologous in different species can be tested for their uptake of certain radio elements and their activity compared. True homologues deal similarly with a given radio element.

THERAPEUTIC ADMINISTRATION OF RADIOACTIVE SUBSTANCES

Since it was known that some substances are selectively absorbed in animals and man, the question arises whether this fact can be used for therapeutic purposes. The idea of intracellular radiation opens up quite a new field of radiation technique. X- or gamma radiation, as normally applied, reaches the cells upon which it is directed by passing through layers of normal cells whose resistance to the radiation constitutes a limiting factor in the dosage attainable. The rays also have a constitutional effect known as radiation sickness, which may assume serious proportions. There is now a large range of artificially radioactive substances which are absorbed by cells and emit their energy from within the cell boundary (22a). They are all temporarily radioactive with a wide range of radiation energy from soft beta rays to high-energy gamma rays, and they can be administered with far less danger of producing radiation sickness.

Radio iodine has been used in a few cases of thyroid disease but is unlikely to be of use for malignant growths in the gland. The heavy

homologue of iodine, known as element 85, was first prepared at Berkeley and has similar properties.

The administration of *radio strontium* is still in the early experimental stage. It is selectively absorbed in bone.

The furthest developments have been made with *radio phosphorus* which has now been used therapeutically on a relatively large scale. Radio phosphorus, $^{32}_{15}\text{P}$, is prepared by the bombardment of red phosphorus with high-speed deuterons (heavy hydrogen nuclei). In the reaction, the proton is repelled and the neutron captured, so that the stable red phosphorus $^{31}_{15}\text{P}$ becomes the unstable isotope $^{32}_{15}\text{P}$ which breaks down spontaneously to stable sulfur $^{32}_{16}\text{S}$ with the emission of a beta ray which can be detected physically. The half-life of radio phosphorus, i. e., the time during which its energy is reduced to one-half by the break-down of its unstable atoms, is 14.3 days. It is usually used as the compound Na_2HPO_4 , disodium hydrogen phosphate, in a dilution of 15 mg. per cc. or the equivalent of 0.4 millicurie of Ra when freshly prepared.

Ordinary phosphorus occurs in all living tissues. A phosphorus atom spends, on an average, about 2 months in the body of a rat before it is excreted. But its speed of movement in different organs of the body varies widely. For example in muscle the uptake, "turn-over," and elimination is rapid and the concentration of phosphorus at any given time low. In bone, on the other hand, the turn-over is slow and local concentration high. In growing tissues the uptake is more rapid than in adult. Radio phosphorus is taken up selectively by bone and bone marrow, spleen, lymph, and liver, and by proliferating cells anywhere both normal and malignant. In the case of bone, the rate at which radio phosphorus is deposited in normal, rapidly growing and cancerous tissue is a function of the activity of the enzyme alkaline phosphatase (22 c). But the results show an individual variation in the actual amount deposited, and a variation for different parts of the same tumor in the case of malignant growths, i. e., when autophotographs are made the fogging of the plates is uneven.

There are certain human blood diseases characterized by the overproduction of blood cells, either the white (leukemia) or the red (polycythemia), and since radio phosphorus is selectively absorbed in the lymphatic tissues and bone marrow where the overproduction occurs, this element has been tried therapeutically in the treatment of these diseases with encouraging results. The uptake of radio phosphorus in leukemia is greatly in excess of that in a normal healthy animal or person, and in a concentration which reduces, at least temporarily, the great excess of white blood cells (fig. 1). If the trouble is an overproduction of red cells, their reduction is effected by a concen-

tration of the salt in the bone marrow, where red cells are manufactured, without disturbing the normal number of white in circulation. The presence of cancer (sarcoma) "screens" both kinds of blood cells so that doses of radio phosphorus which would normally have affected the blood-cell count have no such effect if a tumor is present, as the radio phosphorus becomes concentrated in the tumor cells (pl. 4, fig. 1).

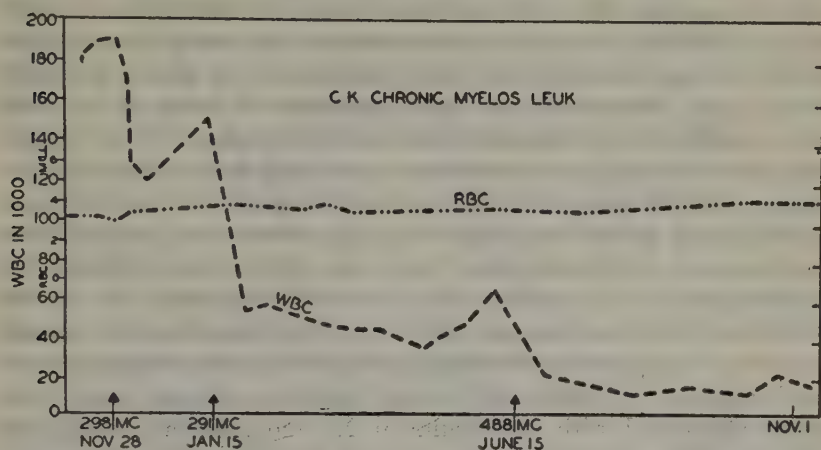


FIGURE 1.—The effect of radio phosphorus in reducing the excessive white-cell count (W. B. C.) in a case of leukemic disease of the blood (22a). The red-cell count (R. B. C.) is practically unaltered.

Radio phosphorus was first used therapeutically in 1936, when it was found that its beneficial effect on certain blood diseases resembled that following X-radiation. It is still early to judge its usefulness, but it is clear already that artificial radioactivity is at least as good as the X-radiation treatment and far less inconvenient for the patient. Neither is a certain cure, but considerable periods of relief are often obtained before the blood shows abnormality again. It is possible that better results will be obtained by a combination of (external) radiotherapy and (internal) administration of radio salts, but it will take some time to determine what is the best form in which to give the combined treatment.

MEDICAL AND BIOLOGICAL EFFECT OF NEUTRONS

The bombardment of beryllium by deuterons in the cyclotron produces a yield of high-energy neutrons which is of sufficient intensity for radiotherapeutic trials. For this purpose the cyclotron (No. 2b of table 1) was made more "presentable" from the patient's point of view by being enclosed in a shell of white-enameled woodwork which concealed the entire apparatus and the protecting screens of wax and

water (pl. 4, fig. 2). A small hole was left through which a canalized beam of neutrons emerged. The attempts began in 1938, and caution was needed because of the danger of serious damage to normal tissue. Cancer patients were chosen, however, whose condition was hopeless from every other point of view. This was perhaps hardly a fair test of the usefulness of a neutron beam in medicine, and it was not to be expected that the results would be in any way spectacular. To begin with, 24 patients, all in the advanced stages of their disease, representing hopelessly incurable cancer, received cautiously administered doses, the magnitude of which was determined in a purely arbitrary fashion (10). Because of the fixed limitations of space, at first only lesions confined to the head and neck could be treated. These experiments served to supply information concerning skin tolerance, depth dosage, and the nature of the primary response of tumor tissue. Later on, with an improved lay-out, a larger number of patients were given neutron irradiation, and these provided a wide diversity of tumors including sites other than the head and neck. So far the results have not been too good (table 3). But neutrons have already caused the disappearance of a malignant growth (23), though no such case is regarded as a cure until several years have elapsed since treatment. Compared with the results of X- and gamma radiation of cancer, neutrons have not so far proved better, but they have been useful in a few instances where X-rays had been tried and failed. It will obviously take time to discover what is the best way in which to give them, e. g., what should be the total dose, intensity, number of exposures, over-all time, the precise method of combination with other types of radiation, and so on.

TABLE 3.—*Some effects of neutrons on cancer*

[See ref. 23b]

Effect	Number of patients	
	During treatment	During succeeding 3 months
Complete regression.....	20	26
Partial regression.....	57	53
No regression.....	43	24
Recurrence in treated area.....	0	3
Dead.....	0	8
Incomplete information.....	0	6
	120	120

A great deal of experimental work has been going on besides the relatively few therapeutic trials which have been made, and the biological effects of neutrons on a variety of tissues have been studied and the results compared with those produced by other types of pene-

trating radiations, both at Berkeley and elsewhere (24). There is, however, as yet no accepted physical unit by which neutron and X- or gamma-ray dosage can be directly compared. If intensity of radiation is measured in ion pairs per centimeter, then neutron intensity is a thousand times that of gamma rays.

At Berkeley the unit dose of neutrons is measured by means of a Victoreen ionization chamber and the dose is described as 1 "*n*-unit" when the Victoreen (calibrated for X-rays) records 1 roentgen.⁷ Measured in these terms, it is reckoned that 1*n* is equivalent to about 2.5 r. (25). The crucial question, however, is whether neutrons can bring about desirable biological reactions which cannot be obtained with other types of radiation. Investigations on the effects of neutrons on cancerous growths in animals as well as human beings were being made, up to the outbreak of war, to test this point. It is possible that best results will eventually be obtained by combining neutron irradiation with other forms of treatment. It is already clear that there are differences in the biological action of neutrons and X-rays, and effort must now be directed to exploit these differences to the advantage of radiotherapeutic treatment.

Neutrons are very penetrating. When "cross-fire" methods are used 30 to 40 percent of the dosage comes from the opposite side. Much work needs still to be done on the comparative effects of slow and fast neutrons (26) and the exclusion of neutrons from regions where they are not wanted.

In spite of their penetrating abilities neutrons are more easily absorbed by such light elements as water, wax, and especially borax than by heavy elements such as lead or platinum, though blocks of lead are used in canalizing the beam for medical and biological experiments (27). The demand for cyclotron time was so heavy when apparatus 2*b* (table 1) was in full running, that it was decided to build a new and bigger machine (No. 3 of table 1) to be reserved for medical and biological work. Before this apparatus was completed plans were begun for the giant cyclotron on the hills behind the University campus. It was decided that protection would be a serious problem with this machine and that it would be best to isolate it as far as possible from other laboratories. Even with cyclotron 2*b* there was unavoidable interference by penetrating neutrons with delicate physical apparatus in nearby laboratories, particularly in the chemical department adjacent to the cyclotron building. The cyclotron team arranged a special signal to warn their neighbors that neutrons were about to be liberated in their neighborhood; it was

⁷ A roentgen is the unit of dosage used in X- and gamma-ray therapy and is defined as the quantity of X- or gamma radiation such that corpuscular emission per 0.001293 g. of air produces in air ions carrying 1 e. s. u. of electricity of either sign.

possible to detect neutrons several miles away. The war has interrupted much of the peacetime research of the medical cyclotron, but a remark by Prof. Sir J. J. Thompson, of Cambridge, at Winnipeg shortly after the discovery of radium applies equally well to the products of the cyclotron: "It is imperative, lest we should be passing over a means of saving life and health, that the subject should be investigated in a much more systematic and extensive manner than there has yet been either time or material for" (18).

Looking down on the Berkeley campus of the University of California, said to be the largest educational center in the world, across the great expanse of San Francisco Bay, with its artificial island of 400 acres and with two of the greatest bridges in the world, the scene is now dominated by the vast circular observatory-like building, 165 feet in diameter and 90 feet high, erected on a hilltop to house the latest cyclotron. As we think of the human activity behind all this achievement the motto on the California State Capitol seems peculiarly appropriate—"Bring me men to match my mountains."

ACKNOWLEDGMENTS

It is a pleasure to acknowledge here the many kindnesses shown me by Prof. E. O. Lawrence, Dr. J. H. Lawrence, and the staff of the Radiation Laboratory at the University of California, Berkeley; I am also grateful to them for permission to use illustrative material from published papers.

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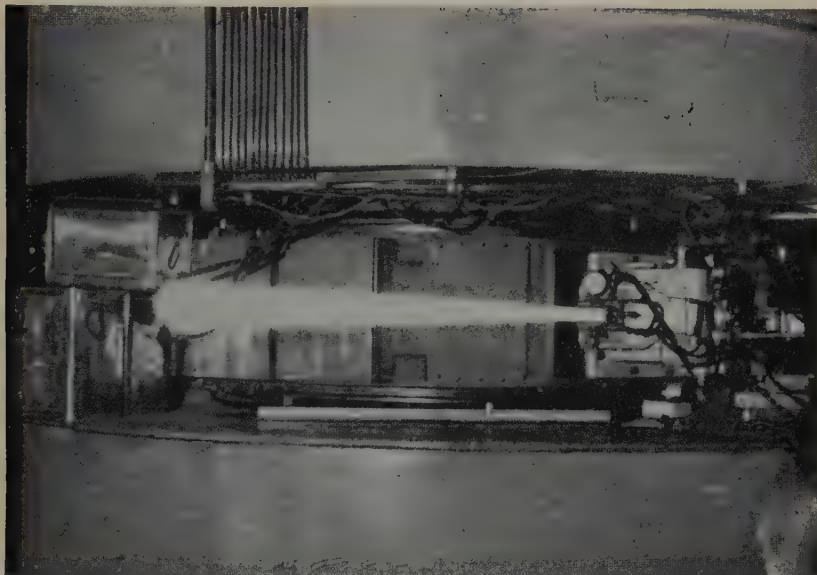
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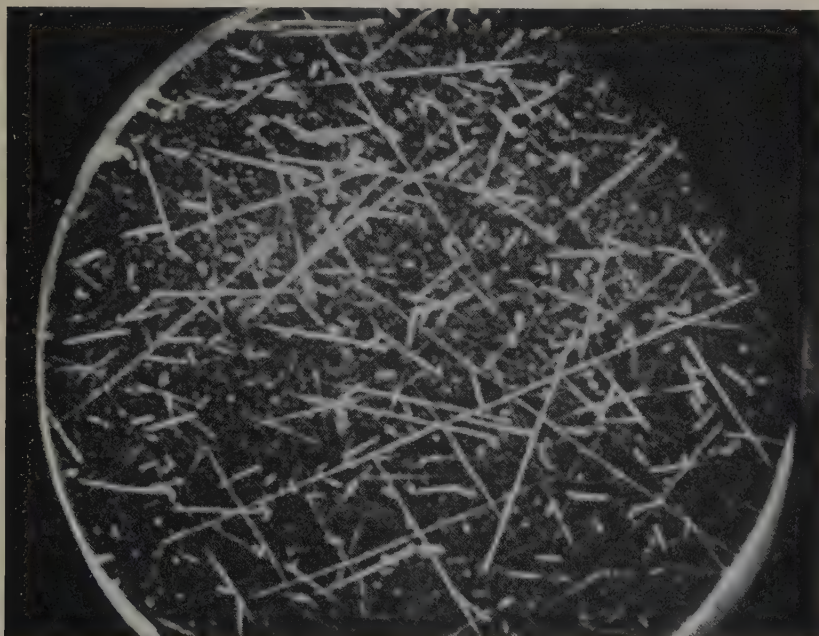
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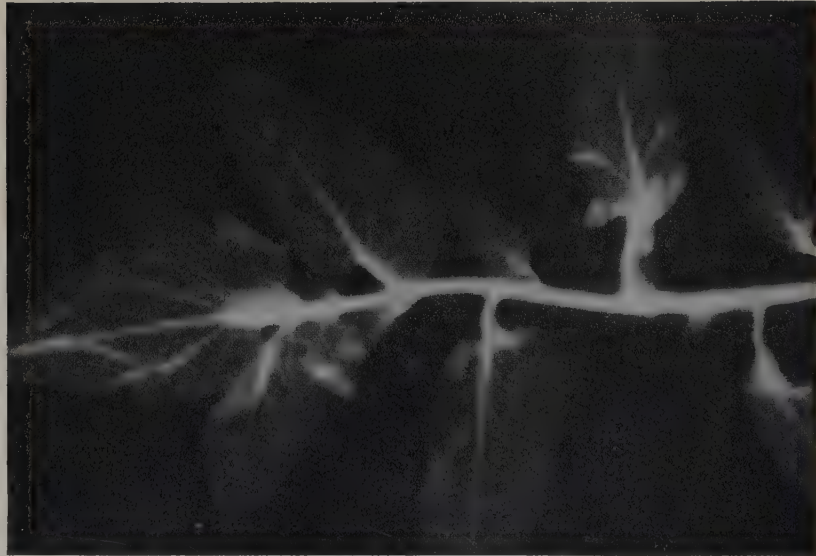
1. CLOSE-UP VIEW OF THE MEDICAL CYCLOTRON (NO. 3 OF TABLE 1).

Showing the 5-foot glow produced when the 16-mev. beam of deuterons is allowed to escape into the air through a thin aluminum foil window which permits passage of the beam but maintains the vacuum in the cyclotron. The beam flares at the end of its path because the deuterons slow down, scatter more easily, and ionize more heavily (15b). A steel plate placed in the beam was melted (14). (Reproduced by permission from Radiology.)

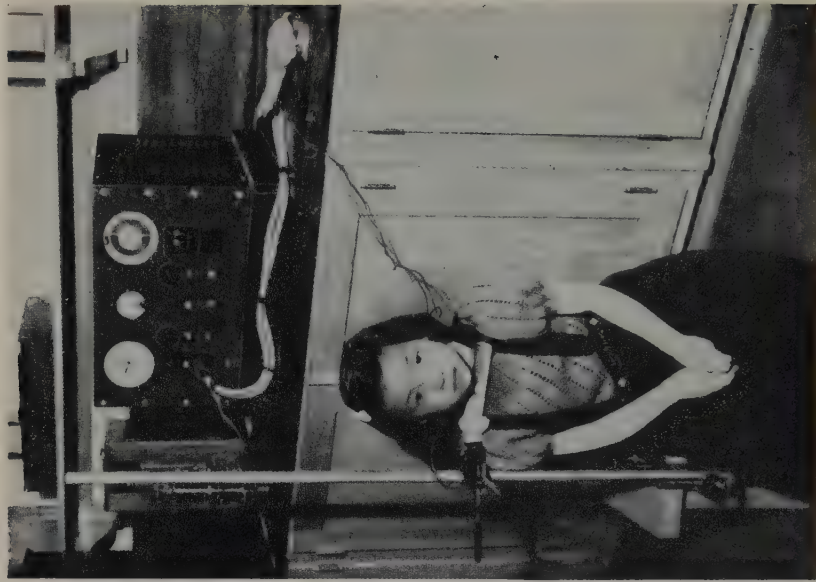


2. WILSON CLOUD-CHAMBER PHOTOGRAPH (1/100 SEC.).

Showing the intensity of the ionization a few feet from the cyclotron (No. 2b of table 1) when producing neutrons.

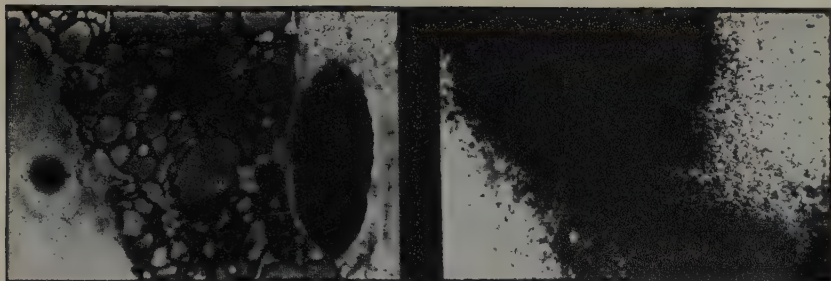


1. AUTORADIOGRAPH OF TOMATO PLANT.
Made 36 hours after the introduction of radio phosphorus into the nutrient solution (16, 18). (Reproduced by permission from the American Journal of Roentgenology.)



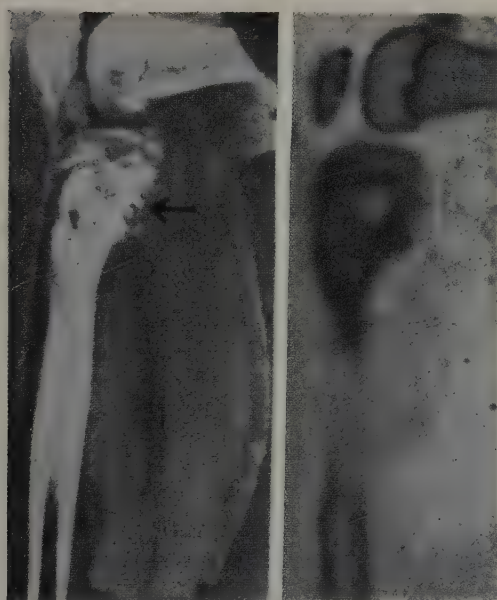
2. THE TECHNIQUE EMPLOYED FOR THE MEASUREMENT
OF RADIO IODINE TAKEN UP BY THE THYROID
GLAND (16).

A Geiger counter placed against the gland is used to determine the gamma radiation emitted from the accumulated radio iodine. (Reproduced by permission from Radiology.)



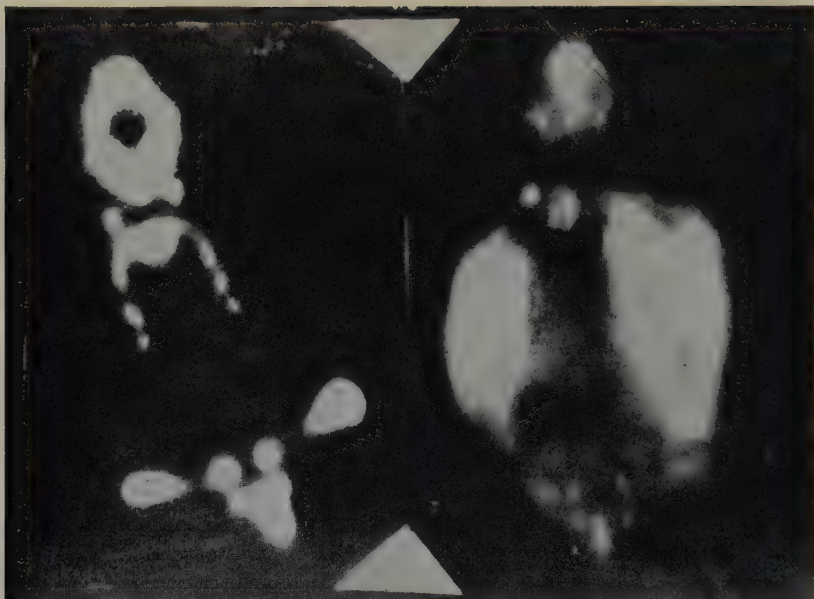
1. PORTION OF THYROID GLAND.

Left, stained section showing oval parathyroid gland on right (16). Right, autoradiograph from the same tissue block showing fogging of plate in region of thyroid gland but absence of any deposit of radio iodine in the parathyroid gland (18). (Reproduced by permission from the American Journal of Roentgenology.)



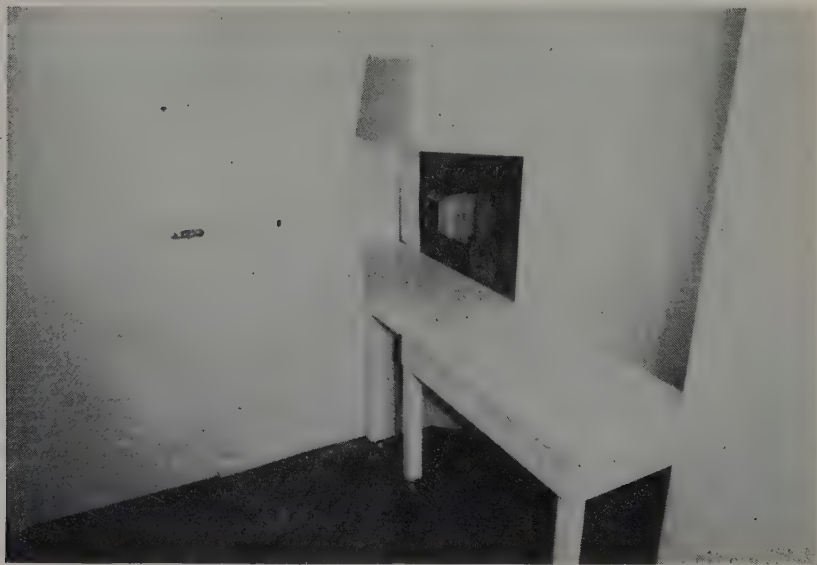
2. X-RAY PHOTOGRAPH (LEFT) AND AUTORADIOGRAPH (RIGHT) OF A SECTION OF AMPUTATED LEG FROM A YOUNG PATIENT PREVIOUSLY GIVEN RADIO STRONTIUM LACTATE (18).

The strontium has been taken up by cancer (osteosarcoma) cells in the leg bone (indicated by arrow in X-ray picture) and by the growing portion (epiphyseal line) of the normal thigh bone (16). (Reproduced by permission from the American Journal of Roentgenology.)



1. AUTORADIOGRAPHS OF TWO MICE CARRYING SUBCUTANEOUS BILATERAL LYMPHOSARCOMATOUS TUMORS.

The animal shown on left was given strontium and that shown on the right radio phosphorus 5 days before the photographs were made (18). The result shows the selective deposition of strontium in bone and phosphorus in the cancer cells. (Reproduced by permission from the American Journal of Roentgenology.)



2. COUCH FOR TREATING PATIENTS ALONGSIDE CYCLOTRON 2B (TABLE 1).

Surrounding water tanks and wax blocks concealed behind white-enameled plywood. The appearance of the apparatus is in striking contrast to that shown in figure 1 of plate 1. (From a photograph provided by Dr. P. C. Aebersold.)

DRINKING WATER FROM SEA WATER¹

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LT. N. PACE, U. S. N. R.

and

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[With 2 plates]

Early in the winter of 1942 the Naval Medical Research Institute became interested in the problem of prolonging survival after shipwreck. At this time the problem of procuring drinking water on life rafts was in a confused state. Several methods had been developed and many proposed, yet no coordinating agency existed to evaluate the methods developed, or make recommendations for those proposed. It was clear that in order to make progress in the problem of survival an agency for coordinating the available data was necessary. Also a need had arisen for answers to certain questions pertaining to the practical and physiological aspects of the problem.

The "Drinkability of Sea Water" (1)² was first investigated because factual evidence on its effects was lacking and various rumors were extant. It was soon learned that sea water was not potable, since greater dehydration occurred with its use than without. This was due not only to the large amount of water required to excrete the salts of sea water, but also to the loss of water by vomitus and diarrhea which frequently followed when the sea water was consumed at a too rapid rate. In fact, it was found that for every volume of sea water drunk, approximately two volumes of fresh water were required to prevent electrolyte imbalance in the body.

Shortly after the experiments with the potability of sea water had been completed, work was instituted to test and develop methods for procuring potable water, to produce a physiological and practical ration, and to provide means for the protection of survivors from the elements, rain, heat, cold, sun, and sea.

¹ Reprinted by permission from United States Naval Institute Proceedings, vol. 70, No. 8. Whole No. 498, August 1944.

² Figures in parentheses refer to bibliography at end of article.

Several methods for preparing drinking water from sea water on life rafts were in a partial state of development. However, no method approached practicability for life-raft use even though available information intimated as much. In fact, few investigators realized that it was a long step from the successful employment of a method under the ideal conditions of the laboratory by skilled laboratory technicians to its use under the trying conditions on a life raft by an inexperienced individual. Those responsible for the evaluation of the various suggestions and devices pertaining to survival at sea soon realized how little knowledge was available and how much had to be learned about the entire problem.

Several methods for producing potable water from sea water had reached a state of development sufficient to merit consideration for life-raft use. The first four methods described below are based on physical devices for producing potable water.

1. *The Visscher body still*.—This still consisted essentially of a vacuum pump to reduce pressure in the system and of a small boiler strapped about the body to utilize body heat for fuel to distill fresh water from sea water. Condensation of the water vapor was achieved by immersing a coil and collecting bottle in sea water.

The still had much in its favor, though the disadvantages outweighed the advantages. It required the expenditure of a significant amount of muscular energy to maintain the reduced pressure; in northern latitudes, a partially fasting individual could ill afford to lose the body heat required for the evaporation of the water. Secondly, considerable machine tooling and engineering were involved in the production of a special vacuum pump which was to be subjected to the corrosiveness of sea water. The weight and volume ratios (water produced per unit of weight or of volume occupied by the apparatus) were very poor. Finally, the loss of any one part made the still useless.

2. *Safety fuel still* (2).—"Canned heat" was used as fuel to distill the sea water and the cool sea water was used to condense the water vapor. The smallest model of this still, though possibly suitable for large lifeboats, was much too bulky and heavy for life-raft use. Furthermore, the still was affected by wind, wave, and rain as well as the corrosiveness of sea water. Considerable manipulation and intelligence were required for operation and, contrary to available data, the still did not produce enough water on a weight-volume ratio to recommend its use. It had many more parts than did the Visscher still so the possibility of the still becoming inoperable through loss of a part was greater.

3. *Armbrust cup* (3).—This method differed but little from a method developed during the last war, whereby the moisture of the

breath was condensed in a wet felt-jacketed metal container. The calculated efficiency peak for such a method is but 15 milliliters of water per hour and even with a tight-fitting mask and a highly efficient condenser this degree of efficiency was never reached in laboratory and field tests. Under experimental conditions a maximum of 5 milliliters per hour was attained and no subject was found who could tolerate the device for 8 hours. Another limiting factor was that the device required quantity production from an already overtaxed metal-working industry.

4. *Delano solar still* (2), (4).—The source of heat for this still is solar radiation. The sunlight passes through a transparent plastic window and is absorbed by black toweling which backs up the plastic sheet. The toweling is kept wet with sea water, and the evaporating moisture condenses on the plastic window and drains into a reservoir at the bottom of the still. Under ideal conditions the apparatus was capable of producing 300 milliliters of water a day, but it was much too fragile for life-raft use. In fact the models tested in the laboratory required continual repair. Another disadvantage was that the apparatus had to be oriented to the sun. On a cloudy day, therefore, the efficiency of the still fell off markedly. In view of these disadvantages and its bulk, the canned water, then available, was to be preferred.

Since all the above devices were unsatisfactory, chemical methods of treating sea water presented possibilities.

5. *Goetz method* (1).—This method was one of the earlier chemical methods and one that received considerable publicity for the reason that the ratio of water produced to the volume of chemical employed was of the order of 14 to 1. It required little manipulation—sea water was scooped into a plastic bag into which was dispersed a small package of silver and barium oxides. The chlorides of sea water were precipitated as silver chloride, the sulfates as barium sulfate, resulting in a solution of approximately 0.3 N alkali which caused the magnesium in sea water to precipitate as magnesium hydroxide. The precipitate was allowed to settle and was then clamped off in the bottom of the bag leaving a cloudy supernatant fluid. Into this was stirred a cake of citric acid which neutralized the sodium hydroxide to sodium citrate. Thus the end result was the conversion of the approximately 3 percent sodium chloride of sea water into approximately 3.3 percent sodium citrate.

The limiting factor in the use of this water was that the sodium citrate was converted by the human organism into sodium bicarbonate, with a resultant severe alkalosis. The kidneys, in order to rid the body of this excess alkali excreted an excess of water, which led to more severe dehydration than if the water had not been drunk. Though

the water was better than sea water, the combination of induced alkalosis and dehydration condemned the method.

6. *Aquamax method* (5).—This relatively simple ion exchange chemical method was limited by the fact that the weight and volume ratio of water produced to chemical employed was too low for consideration. Chemical analysis of the water produced permitted its recommendation as drinking water, but no physiologic studies were made. Development of a field kit would have lowered the ratio still further.

7. *Red Jacket* (6).—This method was similar in principle to the *Aquamax* method. The factor that limited its use was the low weight and volume ratio. A field kit was developed which had much to recommend it for simplicity, but the added weight of the kit resulted in a much lower water ratio.

8. *British Permutit* (7) and *American Permutit* (2), (8), (9).—These methods were very similar and were in fact originally exactly alike. A silver and barium zeolite was employed, which upon interaction with the salts of sea water caused the precipitation of silver chloride and barium sulfate and sodium and magnesium zeolites. The chemical was loosely packaged into a small cartridge, and a number of the cartridges were packaged into a bakelite processing container. The container, shaped in the form of a cylinder, had two removable lids. On one end a filter was placed over a screwed-down cap with a protruding teat. At the other end a screw cap with a rubber vent allowed the formed gas, but not the water, to escape. Sea water was scooped into the container to an inscribed mark, and the contents of a cartridge were added. The top lid was screwed on and the contents shaken for 20 minutes. The processed water was removed by sucking on the teat at the bottom.

Although the original Permutit methods produced excellent water, the ratio of water produced to chemical employed was almost as poor as those of the previously mentioned methods. They had, furthermore, not been considered practical for life-raft use for a number of reasons. First, it was less trouble and expense to package canned water. Second, the method of processing was complicated; the parts at times required mechanical tools for disassembling, especially the screw caps. Third, the method of removing the drinking water was much too difficult. Fourth, the resistance in the filtering system was frequently too great for a man to suck out the water.

9. *Naval Medical Research Institute method* (2), (10), (11).—During the last part of 1942 a new chemical method for the preparation of drinking water from sea water was discovered by Spealman (12). Basically, the method consisted of adding silver oxide to sea water and filtering off the precipitated silver chloride and magnesium hy-

dioxide. Uric acid was then added to the filtrate, precipitating sodium urate which was filtered off.

The method was developed at the Naval Medical Research Institute with field application primarily in mind. Two simple plastic bags and two filters were designed so that minimum space was occupied by these processing devices. The silver oxide was dispersed into the sea water contained in one of the plastic bags. The contents were then filtered into the second bag and the uric acid was dispersed into the filtrate. A final filtration into the first bag, which had been rinsed with sea water, produced potable water. The time required for the complete operation was approximately 30 minutes. The produced water, from a physiologic standpoint, was excellent but the taste although not objectionable was slightly brackish.

The method produced 7.4 volumes of water per unit volume of apparatus, a high ratio. The weight ratio, 5.6 of water to 1 of apparatus, also represented a very substantial improvement over other methods.

The standards for drinking water for life-raft use had initially been set empirically to meet the Treasury Department standards (13). These standards were unnecessarily exacting for water that was to be used for emergency purposes as they were adopted by the Treasury Department on June 20, 1925, for drinking water and culinary water supplied by common carriers in interstate commerce. The attempt to meet these impractical and unphysiological standards was unfortunately one of the prime factors in limiting the chemical methods since the exacting demands lowered the weight and volume ratios.

The first approach to the problem of increasing the efficiency of the chemical methods was to determine how much salt could be left in drinking water. Two groups of men were placed on a semistarvation regime (14) (15) and allowed 500 milliliters and 1,000 milliliters of water per day. One half of each group had its water slightly salted (0.3 to 0.4 grams of sodium chloride per 100 milliliters), the other half drank distilled water. The men drinking distilled water excreted between 3 and 4 grams of sodium chloride daily. The group drinking 500 milliliters of slightly salted water conserved 100 milliliters of water per day more than the comparable 500-milliliter group that drank distilled water. The group drinking 1,000 milliliters of slightly salted water conserved 230 milliliters of water per day more than the group that drank 1,000 milliliters of distilled water. By allowing 0.3–0.4 percent salt to remain in drinking water a considerable reduction was made in the daily water requirement. Furthermore, considerable reduction was made in the chemical required for producing potable water.

It was evident, too, that a further gain in weight and volume ratio could be made if the sulfate ion in sea water was not removed. Current opinions arising from Treasury standards emphasized that sulfate in drinking water should be at a minimum (250 parts per 1,000,000) owing to the suspected cathartic action of the sulfate ion. In order to elucidate this point, experiments were conducted with men placed on a semistarvation regime, who drank 500 milliliters to 1,000 milliliters of water per day prepared from sea water by the Naval Medical Research Institute method (15). In this experiment all the magnesium but none of the sulfate was removed. Ill effects were not observed and all the sulfate ingested in the water (50 ME/liter) was found to be excreted in the urine. The evidence showed clearly that this quantity of sulfate was completely absorbed from the intestinal tract and was not retained by the tissues. Under these circumstances it could not act as a cathartic.

As already mentioned, the Permutit method was a single-step chemical method. Its weight and volume ratios as originally employed, however, were extremely poor. It was demonstrated that if the above adjustments in final chloride and sulfate content were made and if a simple field kit were developed, the ratio of water produced to apparatus employed could be increased to a point where it would be superior to any other available method. The original low weight and volume ratios were due to conformance to Treasury standards which were not in accord with field requirements, and to the absence of a practical field kit.

The following recommendations were consequently transmitted to the Permutit Co.:

1. A collapsible processing container should be developed embodying the principles worked out by the Naval Medical Research Institute and the National Carbon Co., since this container had little volume or weight and was better adapted to life-raft use.
2. The chemical should be formed into highly compressed briquets to conserve space.
3. Sodium chloride should be left in the drinking water to a concentration of 0.3-0.4 percent to increase the weight and volume ratio of the chemical and aid in conservation of body water.
4. The sulfate need not be removed to further increase the weight and volume ratios.
5. A lightproof and waterproof method of packaging as developed by the Institute and the Reynolds Metal Co. should be employed since it not only offered excellent protection against exposure to water and light but added little to weight or volume.

These recommendations were immediately adopted and preparations were made for raft trials, since it now had become obvious that all the laboratory work done would be of no avail if the findings were not proved to apply to actual field conditions.

The modified Permutit method resulted in a briquet of silver zeolite slightly smaller than the size of a package of cigarettes. One had but to drop a briquet into a collapsible bag containing sea water. The new processing bag contained a built-in filter with a sucking tube just below the filter. With a little manipulation the briquet was disintegrated whereupon the chemicals proceeded to react with the salts as described. Twenty minutes of manipulation removed as much of the salts as was necessary to produce potable drinking water. The prepared water was drunk by sucking on the protruding tube at the bottom of the bag. To do this required 3 to 5 minutes.

In February of 1943 the Bureau of Medicine and Surgery authorized the Naval Medical Research Institute to conduct sea trials under simulated conditions of survival on life rafts in the Gulf of Mexico.³ The primary objective was the testing of various methods of producing drinking water from the sea. The secondary objectives were observation of the suitability of a new tablet ration, methods for prevention of sunburn, and, in general, of the performance of life rafts and equipment, such as signaling devices, water-collecting devices, fishing gear, and clothing, as well as a study of available space and the physiologic phenomena of shipwreck survival such as water requirement, incidence of seasickness, and conservation of body water. The following water-making devices, all in a rather well-developed state, were tested: the Naval Medical Research Institute method, the Permutit method as modified by the Naval Medical Research Institute, the Delano solar still, and the Safety fuel still.

From July 7 to 11, 1943 (2), 21 men,⁴ ages 19 to 44, spent 97 hours on a restricted regime with the daily fluid intake limited to 500 milliliters, and a dietary intake of approximately 330 calories in the form of tablet rations in which chewing gum and vitamin concentrate were included.

Sixty-one of the 96 hours, including 2 nights, were spent floating in rafts 10 to 20 miles offshore in the Gulf of Mexico, near Pensacola, Fla. The remaining time was spent on the escort vessel. Rafts included Navy one-man parachute rafts, Navy four-man rafts, and a special seven-man raft supplied by Transcontinental and Western Airlines. Each was captained by one of the staff members of the Naval Medical Research Institute.

³ Plans for these sea trials were made with the cooperation of the Liaison Committee on Emergency Rescue Equipment of the Office of the Coordinator of Research and Development of the U. S. Navy.

⁴ The following were the men who volunteered as subjects for the foregoing raft trials: Lt. P. H. Fitcher (MC), U. S. N. R., Lt. W. V. Consolazio, H-V (S), U. S. N. R., Lt. N. Pace, H-V (S), U. S. N. R., J. D. Blackburn, PhM1c, T. C. Watson, PhM1c, C. N. Crouse, PhM2c, N. L. Krueger, PhM2c, J. N. Shaner, PhM2c, C. N. Saracco, AMM2c, L. L. Nullmyer AMM2c, M. C. Wallace, AOM1c, S. Olexen, AMM2c, H. A. Schramm, AOM3c, J. B. William, AMM3c, M. H. Smith, ARM3c, Lt. (jg) D. V. Kirchberg, A-V (N), U. S. N. R., Lt. (jg) G. E. Pantano, A-V (N), U. S. N. R., Dr. D. Blaine, U. S. P. H. S., Lt. A. L. Budlong, U. S. C. G. R., W. G. Henry, W. H. Hall, J. J. Walters.

With the exception of the seven-man raft, all rafts were to depend for their drinking water on the particular type of water-making device delegated to each raft, e. g., one raft contained four Delano solar stills. The seven-man raft was to depend on the Safety fuel still for its water supply; other water-making devices were supplied to this raft for test purposes only. When the water produced was below 500 milliliters per day per man, the deficient quantity was supplied to the individual from the water supply of the escort vessel.

Water volumes produced by the various methods tested were measured and logged by the raft captain. He noted also whether the other occupants of the raft were able to carry out their assigned methods from printed directions, and what difficulties were encountered, if any. No assistance was rendered by the raft captain unless the subject could proceed no further.

On the early morning of the first day all subjects went over the side of the escort vessel and into their designated rafts. Water-making devices were broken out whenever the time rose for producing water, except for the solar stills which were in operation as soon as the individuals could get their appliances together.

Of the original 21 individuals starting as subjects, 3 had to be removed on the second and third days, owing to seasickness. All but 3 of the remainder also suffered from seasickness but became adapted by the end of the second day.

The following requisites relative to water-making devices were noted:

1. A method for field use must be made extremely simple since the effects of exposure to cold, water, heat, sun, hunger, and thirst, plus the added factors of lack of sleep and seasickness leave men in a poor mental and physical condition.

2. The method employed should require little time for its operation or manipulation and few directions. It was found that the individuals tended to employ the warm daylight hours for catching up on lost sleep.

3. The device employed should have a minimum of parts and all parts should be well secured to the person or to the raft.

4. The device employed should be of rugged construction and resistant to corrosion.

5. The complete kit should occupy very little space in the raft since space was at a premium.

As expected, the method of first choice was found to be the Permutit method as modified by the Naval Medical Research Institute. It required fewer directions and less time, attention, and manipulation than any of the others. Several minor faults were found that were corrected later.

1. The closure on the plastic bags was made more secure.

2. The filter was bonded into the bag to prevent leaks caused by sharp particles of chemical being trapped in between the filter and bag which, upon kneading, caused pinhole breaks in the bag.

3. The sweetish taste, about which complaints were made during the raft trials, was found to be imparted to the water by the Vinylite plastic bag caused by the lubricant employed in the manufacture of sheet Vinylite. The taste was eliminated by heating the finished fabric to 160° F. to evaporate the solvents and lubricants employed.

The method of second choice was the Naval Medical Research Institute method. This method, involving two stages, required double the time, attention, and manipulation of the Permutit method. However, it still possessed the advantage of higher weight and volume ratios.

The third choice was the Safety fuel still, to which there were however, many objections. It occupied an excessive amount of space in the seven-man raft, the igniting flints quickly became corroded and useless, and corrosion also affected the still itself. The lighting of the fuel was a serious problem, especially in high seas and high winds, the burning fuel gave rise to fumes irritating to the already physically upset subjects.

The solar stills were not even considered for use. They were continually in a state of disrepair. In fact, of the original five employed, none were in working order after the third day. They required continual attention and always had to be oriented to the sun. The maximal water production was of the order of 150 milliliters per day. They had to be carefully put away at night so that no damage might come to them in the crowded raft.

The comparative data on all the water-making devices tested on the life rafts are presented in table 1.

TABLE 1.—*Summary of comparative data on water-making devices tested on life rafts*

Process	Mandays of water produced	Degree of manipulation	Attention required by operator	Volume water produced per operation	Volume water produced per hour	Unpackaged		Remarks
						Volume ratio	Weight ratio	
Permutit as modified by the Naval Medical Research Institute.	20	+	+	480	960	5.76	5.44	Simplest method to operate.
Naval Medical Research Institute.	20	++	++	950	950	7.44	5.56	Not difficult to operate on raft.
Safety fuel still.....	140	+++	++	762	762	3.33	5.56	Subject to elements. Too many parts.
Solar still, Delano.....	-----	++++	++++	54	5	.28	1.52	Very fragile. Tedious in operation.

Owing to the fact that the chemical had been compressed to the maximal degree consistent with disintegration on use, the Naval Medical Research Institute method produced considerably more water by volume than any of the other methods tested. Greater compression

of the chemical was, therefore, recommended to the Permutit Co. It was pointed out, however, that too much pressure made the briquets indispersible and, therefore, useless. Fortunately, an earlier observation at the Naval Medical Research Institute permitted much greater compression than had formerly been possible. If an inert chemical which swells to 6 to 12 times its original volume when exposed to water is added to the briquets, it acts as a disruptive agent. This development was incorporated into the new Permutit briquets, and proved very successful. The result has been that an exceptionally small briquet can now be manufactured which, within a minute after being added to sea water, crumbles and falls apart into very small sandlike particles.

Table 2 presents the water analysis of the major constituents of the drinking water produced by this process.

TABLE 2.—Salt content of water produced by the Permutit method as modified by the Naval Medical Research Institute

Ion	Typical sea water	Treated water
Sodium.....	435	80
Magnesium.....	96	5
Chloride.....	495	40
Sulfate.....	47	47

All values are maximal and are expressed as ME/liter.

Briquets with the latest modifications are now in mass production and are being packaged in a can exactly the same shape and volume as the standard Navy water can. This design was chosen by the Naval Bureau of Aeronautics in order to minimize changes in the parachute back pad and parachute type raft. Calculation from the figures given in table 1 shows that the new briquet yields the following ratios as compared to packaged water:

	Demineralizing equipment	Packaged water
Weight ratio.....	5.4	0.7
Volume ratio.....	7.1	0.5

This can, filled with water, occupies a volume of approximately 700 milliliters and weighs approximately 512 grams, containing a volume of water of 340 milliliters. The same can, containing demineralizing equipment, has a total weight of approximately 800 grams for a total volume of approximately 700 milliliters. The demineralizing equipment will have a potential supply of 3,000 milliliters of water, a gain of approximately nine times the available water for the same given space. The man-days of available water (500 milli-

liters per day) for the same volume of space is 6 man-days for demineralizing equipment as against 0.7 man-day for packaged water.

Directions are stamped on the processing bag in waterproof ink. The directions were written in very simple English so that they might reach all types of unindoctrinated individuals.

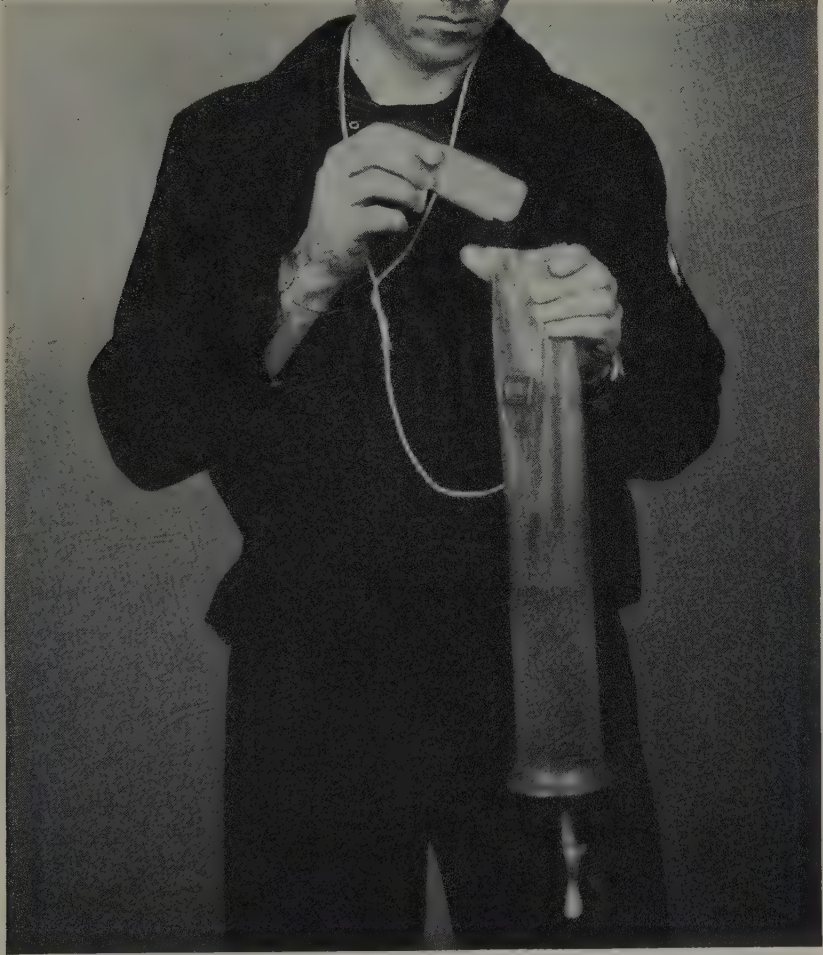
The following are the printed directions as stamped on the processing bag:

1. Screw plug in outlet tube at bottom and fill bag to line with sea water.
2. Add briquet. Tightly roll top of bag down toward buckle and strap securely.
3. Allow briquet to stand in contact with water for a few minutes. Then gently knead bag with hand for 10 minutes until entire briquet is broken into a fine powder.
4. Shake bag occasionally for at least 20 minutes more, so that desalting material is kept in thorough contact with the water.
5. Now suck clear filtered drinking water through drinking tube.
6. After sucking out all water, rinse bag in sea water to remove used-up desalting material.

These developments have led to the adoption of the Naval Medical Institute modification of the Permutit method by the Naval Bureau of Aeronautics, the Army Aviation Corps, and various private airlines operating with the Army and Navy, and it is now being considered by the War Shipping Administration for possible use on transports and freighters.

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ADDITION OF DESALTING BRIQUET TO PROCESSING BAG CONTAINING SEA WATER.



1. KNEADING DESALTING MATERIAL WITH SEA WATER.



2. DRINKING DESALTED SEA WATER FROM TUBE AT BOTTOM OF PROCESSING BAG.

PLASTICS AND METALS COMPETITORS OR COLLABORATORS?¹

By G. K. SCRIBNER

*President, Boonton Molding Co.,
Boonton, N. J., and Past President
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[With 2 plates]

Any attempt to compare plastics and metals on a competitive basis is difficult because of the versatility of both groups of materials. It is in the same class with the ancient discussions of which is the more valuable man on a baseball team, a good hitter or a good pitcher. Both are necessary to a well-rounded team. Our team in this case comprises all the materials of engineering that are making possible the present and future scale of living for all of mankind.

The general idea that plastics will in some way be competitors of metals (especially light metals) in the postwar world may be true to a certain extent, but the areas of overlapping will be found to be comparatively small. In the first place, plastics are not a tonnage industry as practically all metals are. Even magnesium, the newest candidate among the metals, is being produced at something like double the entire output of plastics. If the automotive world suddenly decided that plastic cars were actually here and tried to swing into production, it would put the chemical industry in an impossible situation. Three hundred and fifty thousand tons of plastics (the present production for parts) would not go very far, and the tanks, retorts, and piping required to jump plastics production up to anything approaching the tonnage required would be a real headache.

Even in the competitive area, the rivalry is not general. Molded plastics compete with metal chiefly when metals are die-cast, sand-cast, or machined. Laminated plastics are competitors with metals when the latter are considered in sheets, formed or machined. Resin coatings compete with metals used as plating mediums. These are the three principal occupants of the twilight zone where plastics and metals overlap.

¹ Reprinted by permission from *Metals and Alloys*, vol. 20, No. 2, August 1944.

Outside this area the two types of materials are mutually exclusive—each supreme in its own right. Plastics cannot be used where continuous heat above 400° F. will be applied. Plastics lack the surface hardness of most metals, although many plastics seem to be better under abrasion than many metals. Again, if only a small space is available and the cross section therefore limited, metals are invariably chosen because they provide the requisite strength.

SOME BROAD DISTINCTIONS

Plastics are beyond the competitive reach of metals where (1) satisfactory electrical insulating quality is required; (2) a material is needed that will waterproof textiles so as to leave them flexible enough to use as raincoats, shower curtains, and the like; (3) transparency is required; (4) a material is sought that is suitable for protection against ordinary heat conduction in such simple applications as coffee-pot handles, gas-stove handles, electric-iron handles and thousands of like parts; (5) the material must feel warm and comfortable to the touch, so that one's skin won't freeze to it in cold weather, and must not get too hot to handle in very hot weather; and (6) a choice of built-in colors is desired.

If those were the sole bases of comparison between plastics and metals, metals would already be at the start of a long decline. However the problem cannot be settled so simply in favor of either side. Let us go back to the two most important fields where the choice may be difficult—formed metals versus molded plastics and sheet metals versus sheet plastics, and see if it is not necessary to draw some finer distinctions.

To begin with, not all metals can be formed with equal ease. As with plastics, compromise is usually invoked. A certain alloy steel may be ideal as to service quality but to get it in the shape needed might involve so much cost as to make its specification unwise. If some bright engineer found an airplane propeller design that needed a metal so hard to work that it would cut the entire propeller production of the country to one-tenth its present rate, it is unlikely that the advantages accruing from its use would be considered enough to justify the loss of production.

Molded plastics need rather expensive steel molds, but so do metal die-castings. Sand-cast metals offer a cheaper approach, but may leave too much machining to be done to get the needed accuracy. Plastics molded parts seem to fit into a middle band of accuracy. If the part is really rough and a sixteenth of an inch means nothing, a sand-casting is certainly indicated; if the tolerances, however, are less than 0.001 inch, carefully machined metal is a better choice; be-

tween these two sections is where molded plastics may have an even chance.

Other things being equal, the greatest advantage plastics have to offer the prospective buyer is built-in color, and its twin brother, surface permanence. In the case of plastics neither corrosion nor electrolysis will alter what was bought and paid for.

Die-cast or stamped metal is most certainly indicated when thin sections must be rigid or bear any appreciable strain. Strong, thin plastic parts can easily be made in limited shapes by using reinforcements of laminates or fiber stocks, but they will not be rigid. On the other hand, plastics can carry threads very nicely, as nicely indeed as metals if there is enough "meat" around the thread to prevent its cracking out.

ENGINEERING FACTORS IN SELECTION

Basically the first factor determining the choice of plastics or metals is the available space or volume of the part. If it is relatively small, plastics are almost automatically out unless their use is demanded by one of the six "exclusives" mentioned earlier.

After the space factor comes cost. All plastics cost more than metals, on a pound basis. The saving grace for plastics comes from the advantage of their low specific gravities. (See table 1.) Even magnesium at 1.80 is higher than the average range of 1.06 to 1.50 for plastics. Perhaps, indeed, a correction of the usual strength values for the specific-gravity effect may bring plastics up into the range of the engineering metals. Unfortunately, to make any showing at all for plastics we must choose the very best plastics material, and be careful to select one of the weaker alloys for comparison.

On this basis, for instance, let us make some tensile-strength comparisons. (See table 2.) Chrome-moly steel and stainless steel run around 180,000 pounds per square inch, aluminum alloy 62,000, and magnesium alloy 46,000. One of the strongest plastics we have is Pregwood, impregnated plywood. Pregwood's tensile strength is 30,000 pounds per square inch. Other "strong" plastics are paper laminate at 12,500 pounds per square inch, canvas laminate 9,500, and wood-flour-phenolic molded parts 8,500. It is evident that plastics offer no competition in direct comparisons of this type.

Now suppose we set up our system of handicaps based on dividing the strength figures by specific gravity so we can determine specific tensile strength or tensile strength per pound. (Again see table 2, in which the materials are listed in their order of merit in this respect.) Immediately one of the plastics contestants, Pregwood, moves up to third on the list at 23,000, behind magnesium alloy at 25,400, and

stainless steel at 23,600. Chrome-moly steel comes in at 22,900, aluminum alloy at 22,100, and then a terrible drop to paper laminate at 9,400, canvas laminate at 7,100, and wood-flour-phenolic, molded, at 6,200.

This comparison shows that if the competition be confined to sheet materials, the plastics stand up fairly well in tensile strength by weight, but the moment it centers about really shapeable forms by bringing in the moldable group, the plastics lose position rapidly.

TABLE 1.—*Some plastics and metals compared as to light weight (lightest at the top of the list)*

Materials and characteristics	Specific gravities
Formica Pregood No. 100. Impregnated compressed wood.....	1. 30
All laminations parallel. Classed as a high-strength product.	
Water absorption 6 percent maximum.	
Formica canvas laminate-phenolic. Grade C.....	1. 33
Cotton fabric, 4 ounces per yard. Tough.	
Water absorption 0.3 percent.	
Formica paper base laminate-phenolic. Grade X.....	1. 33
Primarily for mechanical applications.	
Water absorption 4 percent.	
Bakelite wood-flour-phenolic BM-120. Best all-around molding composition.....	1. 36
Water absorption 0.3 percent.	
Bakelite macerated canvas phenolic BM-3510.....	1. 38
High-production, high-impact molding.	
Water absorption 1 percent.	
Formica glass mat base phenolic. Grade MF.....	1. 50
Basically for electrical purposes.	
Water absorption 0.35 percent.	
Formica asbestos fabric base laminate. Grade AA.....	1. 80
Strength, toughness, minimum dimensional changes.	
Water absorption 1.5 percent.	
Magnesium alloy (AM-585).....	1. 81
Aluminum alloy (24 ST).....	2. 80
Stainless steel.....	7. 85
Chrome-moly steel.....	7. 85

With respect to compressive strength the steels are strongest; with some of the plastics better than some of the other metals, as can be seen in table 3. When the specific gravity correction is applied, however, all the plastics (except Pregood, now) rate higher than the metals. Therefore if compressive strength is the determining factor in a specific design, plastics (some form of thermosetting phenolic or urea) will serve the purpose best pound for pound.

Similar data on modulus of elasticity in tension, which is a measure of a material's rigidity, are given in table 4 and show clearly that the metals are outstanding in this respect, even on a per-pound basis. And beyond that, on shear strength, impact strength, and flexural strength there is just no point in presenting tables, no matter how they might be corrected for comparative weights, for the plastics are woefully inferior to metals in these respects.

THE CASE FOR PLASTICS

Faced by this story of comparative performance, why don't plastics fold up and leave the field of engineering materials entirely to the metals? In ninety-nine cases out of a hundred, when a plastic material is faced with a really severe service application of an engineering nature it does fade right out of the picture—unless the stronger metal has its own handicap (such as poor resistance to corrosion or even electrical characteristics) that may be even more serious than the mechanical deficiency of the plastic.

Fortunately for plastics there are enough applications for which any material will have enough strength if it can be dropped six times from the height of a table to a concrete floor without breaking. Certainly if you can design around compressive strength, almost any kind of thermosetting plastic material, except plywood, will give the best results on a pound basis. Under tension, plywood is right up in the front fighting it out with the leaders in the metal world on a pound-for-pound basis, asking no quarter and giving none. That is the reason the famous Mosquito bombers are made of plywood (actually a different kind of wood for each part of the structure, birch in one spot, boxwood in another, etc.).

Plastics have a few outstanding service qualities where these previously mentioned measures of strength are not all-important. One of these is abrasion resistance. Ammunition chutes of laminated phenolic outwear steel. Plastic gears are not only quieter but wear as well as steel. Under impact plastic sheets won't dent and gradually deform before failure, but will just break all of a sudden, while metal, although it will not fail completely, will get battered out of any usable shape. Plastics will dampen vibration better than metals, too, which means less noise, or the avoidance of synchronous beats set up in other parts of a machine.

TABLE 2.—Comparison of strength/weight properties of plastics and metals

Material	Specific gravity	Tensile strength	Tensile/specific gravity	Ratio (magnesium alloy = 100)
Magnesium alloy	1.81	46,000	25,400	100
Stainless steel	7.85	185,000	23,600	93
Pregwood	1.30	30,000	23,000	90
Chrome-moly steel	7.85	180,000	22,900	90
Aluminum alloy	2.80	62,000	22,100	87
Paper laminate	1.33	12,500	9,400	36
Glass fabric laminate	1.50	14,000	9,300	36
Canvas fabric laminate	1.33	9,500	7,100	28
Wood-flour-phenolic, molded	1.36	8,500	6,200	24
Asbestos paper laminate	1.80	10,000	5,500	21
Impact phenolic, molded	1.38	7,500	5,400	21

TABLE 3.—*Compressive strength/weight values of plastics and metals*

Material	Specific gravity	Compressive strength	Compressive strength/specific gravity	Ratio (canvas laminate=100)
Canvas laminate.....	1.33	38,000	28,000	100
Paper laminate.....	1.33	35,000	26,000	93
Glass fabric laminate.....	1.5	40,000	26,000	93
Impact phenolic, molded.....	1.38	35,000	25,000	89
Wood-flour-phenolic, molded.....	1.36	30,000	22,000	78
Asbestos laminate.....	1.80	38,000	21,000	75
Magnesium alloy.....	1.81	35,000	19,300	69
Chrome-moly steel.....	7.85	150,000	19,100	68
Stainless steel.....	7.85	150,000	19,100	68
Aluminum alloy.....	2.80	40,000	14,300	51
Pregwood.....	1.3	15,000	11,000	39

Sheets of plastic cannot be drawn to new shapes as easily as metals, but usually when odd shapes are wanted they can be created in plastics before making the sheet itself; in other words, sheets of metals are raw materials suitable for a great deal more working than sheets of plastics. The plastics man starts one step back of the sheet, uses the same basic material and pre-forms it to the desired shape instead of into the sheet itself.

There is one unfortunate characteristic of plastics that occurs also in metals but not so badly, and that is creep. Creep (cold flow in this case) is the constant change in dimension under stress. The thermoplastic plastics are strongly subject to it and therefore are avoided for stressed service; in the thermosetting materials creep is present but unless the material is used with practically no factor of safety it may be discounted entirely.

CLASSES OF PLASTICS

In any comparison of plastics and metals it should be remembered that there are many types and forms of "plastics." All plastics are divided into thermosetting and thermoplastic types. The first group, the thermosetting, are somewhat like concrete in their internal action. As raw materials they will first soften under heat and then harden. Practically no further softening will take place right up to the charring point. A part once molded wrong might as well be scrapped, since the material cannot be used over again. (Like all technical statements, that one must immediately be qualified. It has been reported that the H. J. Heinz Co., of 57-variety fame, developed a liquid that would soften a completely cured phenolic part, than which there is no more completely set item thinkable, so that the part could be manipulated by hand, and would come back to its original hard state when dried. Also, some of the airplane companies on the west coast have a process whereby

they can shape within certain limits laminated structures that have been considered completely cured. With those reservations our definition of thermosetting is still good.)

The thermoplastic materials, the other general class of plastics, are those which have the quality of softening under heat and hardening when cool; a simple analogy in this case is paraffin.

The thermosetting group are usable on an average up to around 300° F.; some will go to 400° F. The moldable materials that go above those figures are based on cement binders as a rule and are not classed as plastics. Thermoplastic materials, as a rule, are not rated much above 130° F. although the laboratories promise some that can be boiled, for production in the near future.

There is one outstanding characteristic about metals that we who handle plastics regard with wistful envy. The word "metals" covers a number of different materials and everybody accepts that fact without question. So does the word "plastics," but few people seem to recognize *that* fact. Perhaps an illustration will make significance of this statement clearer:

Suppose the hardware stores stocked ordinary house gutters of two or three different kinds of plastic materials, and that John Doe decided to buy one and bought the cheapest he could find—to be specific, one made of cellulose acetate. On an August day in Philadelphia it would probably sag from the heat and become useless. The odds are that he thought of the gutter as "plastics" rather than as *an acetate plastic*, and when it proved unsatisfactory he would simply condemn all plastics and decide never to buy another plastics gutter.

On the other hand, suppose he bought a cheap black iron gutter and in 3 or 4 months that gutter rusted out. Again the odds are that he would merely scratch his head and admit that he should have known better and bought a copper gutter in the first place. He definitely would not have condemned *metal* gutters.

The moral is that we to whom plastics are bread and butter have been lax in educating the public to the fact that there are a whole series of plastic materials, each of which has a different set of qualities, so that if a wrong application is made of one of the series (and there are bound to be mistakes made) the whole class of plastics will not be condemned. We should begin that education with engineers and then try to make it filter down to the general public. Unfortunately, even some engineers disparage plastics generally because they made a mistake in the choice of one of the line.

TABLE 4.—*Moduli of elasticity in tension and specific gravities of plastics and metals*

Material	Specific gravity	Modulus of elasticity	Modulus/S.G.	Ratio (stainless = 100)
Stainless steel.....	7.85	30×10^6	3.8×10^6	100
Chrome-moly steel.....	7.85	29	3.7×10^6	98
Aluminum alloy.....	2.80	10.4	3.7×10^6	98
Magnesium alloy.....	1.81	6.5	3.6×10^6	94
Pregwood.....	1.30	3.7	2.84×10^6	76
Paper laminate.....	1.33	3.0	2.25×10^6	59
Glass fabric laminate.....	1.50	2	1.34×10^6	35
Impact phenolic, molded.....	1.33	1.8	1.30×10^6	34
Canvas laminate.....	1.33	1.5	1.12×10^6	29
Asbestos laminate.....	1.80	1.5	0.84×10^6	22
Wood-flour-phenolic, molded.....	1.36	0.96	0.70×10^6	18

SPECIFIC MATERIALS

A recitation of many branches of the plastics family tree may help to clarify the possibilities of future applications and their relations to metals. The two basic classifications of thermosetting and thermoplastic are merely behavior classifications. First let us remember that plastics are the children of organic chemistry—permutations and combinations of the five elements carbon, hydrogen, oxygen, nitrogen, and chlorine, with minor assistance from many others.

The top division among plastics would group them into rigid and nonrigid, rigid plastics being those which require substantial force to deform, and which show only a moderate deformation under the stress of usage. This would probably mean an elongation in tension of less than 100 percent and possession of appreciable flexural strength. This is the general class of materials meant when we talk about plastics. The materials that lie outside the rigid group are the elastomers such as the Bunas, Butyl, Thiokol, Neoprene, and the like.

The rigid plastics may then be divided into three general groups, the thermosetting resins, the thermoplastic resins, and the cellulosic. Even after that break-down we should perhaps recognize a fourth and straddling group of "natural" plastics to accommodate such materials as lignin, casein, cashew nuts, redwood, coffee, and such.

Among the thermosetting resins there are phenolformaldehydes (commonly called phenolics), phenolfurfural, urea formaldehydes, and melamine formaldehydes. They are all furnished to the molder or laminator in a preliminary state of chemical change and are completed or cured by the heat applied in the forming operations. A chemical reaction takes place in the mold so that when they come out of the mold or laminating press they are different chemically from the materials that went into the presses. Each will maintain its new identity indefinitely if properly treated.

The thermoplastic group is the one that constantly fills the headlines and carries most of the glamour today. It is the one that furnishes the shoe soles, the shower curtains, the transparent food packages, and so on. In it are the acrylates of bomber-nose fame, styrene, polyethylene, nylon, vinylidene chloride, and the vinyl family—a most versatile group of chemical relatives who can do almost anything, including belonging to either the thermosetting or thermoplastic class at the command of the chemist in charge.

Then comes the cellulosic section, made up of cellulose acetate, cellulose nitrate (the forefather of them all, but a frequent problem because of its inflammability), cellulose acetate butyrate, and ethyl cellulose, one of the latest comers. These are not resins, but compounds. Each has been loaded down with a lubricating agent, of which the chemist has a list of a couple of hundred at his fingertips.

Finally there is that catch-all class, the naturals. Nature uses the same general formula that the plastics industry uses. All things inanimate that grow consist of a filler (cellulose) and a binder (some sort of lignin). That binder has tempted the chemist mightily ever since plastics became good headline materials. Coffee, soy beans, cashew nuts, walnuts, redwood, all have been found to have possibilities. All seem to contain something resembling aldehydes or phenols in their composition. They have been successful in coatings and in large sheets for wall boards but the basic formula is not consistent enough to show any particular promise in molding.

If the field of competition between plastics and metals is small, the question naturally comes up as to whether metals and plastics should merely pass each other by with a nod. Definitely not. The main use of plastics today and in the future is complementary to metals.

Plastics must add to metals the characteristics that metals lack, and they are already doing just this in many surprising ways. Plastic quick-drying varnishes put the automobile into the low-price class it had to hit if it wanted volume. Remember when it took weeks to finish a repaint job? Busy weeks too, on the part of the painter, weeks spent in rubbing down successive coats and careful drying in between. Now the dipped or spray sections are dried progressively in tunnels. Imagine, if you can, thousands of cars per day under the old system.

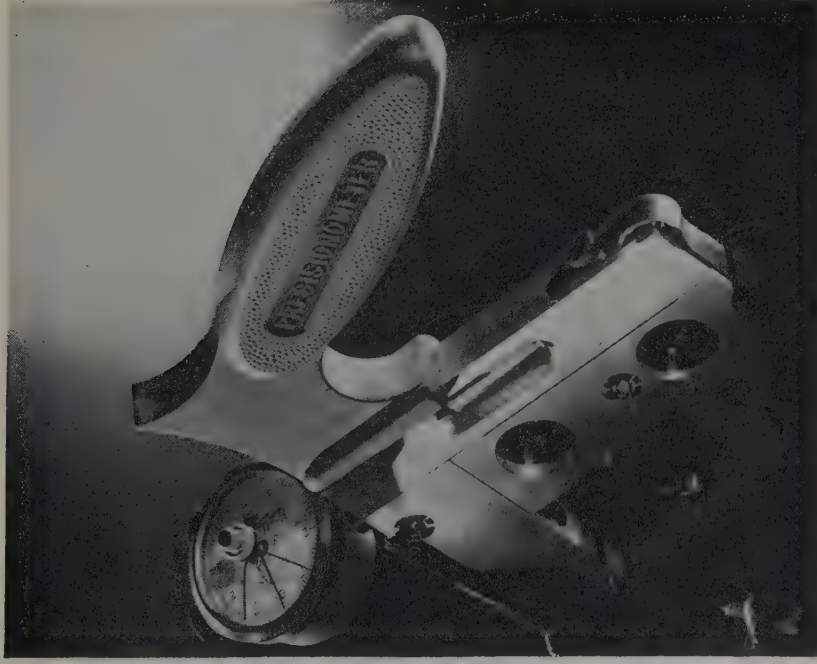
In automobile hardware we have the ideal illustration of the combination of desirable qualities in metals and plastics—die-cast zinc alloy cores for door handles covered with thermoplastic colors, warm to the touch and everlasting, the strength and rigidity of the die-cast metal counteracting the tendency of the plastic to droop in heat or under too much pressure. Business machines of all kinds have metal bases for rigidity, metal gears for small, strong sections, and

plastic parts for complications and housings. Plastics can handle electricity but welcome metal for protection and for the boxes that are fastened to the wall. Airplanes have hundreds of plastics parts, where the light weight really does a job, but combined with metals where metals are helpful from the strength standpoint. The list of such combinations is endless.

I recently saw an all-plastic alarm clock, a completely illogical try if ever there was one. The combined cost of molds and molded parts would have placed the selling price at four or five times that of any much better metal clock. And yet there are good reasons for clock cases finished in plastics. Color, the low cost of intricate shape, warmth to the touch, etc., in combination with the basic metal design make a salable article.

In considering plastics as design materials, therefore, please remember two things: First, there are many plastics, just as there are many metals; if one plastic does not prove the answer to your problem, look around a bit and see if there isn't another that is more logically suited. Second, include plastics in your design thinking as a complementary material to your metal experience; investigate every possibility of combining a metal and a plastic to utilize the best features of each.

The very fact that plastics production is only 350,000 tons per year compared to the relatively enormous production figures of metals (90 million tons of steel, 1 million tons of aluminum, etc), tied to the widespread discussion of plastics in the public press and in engineering magazines like this must mean only one thing: no material with that small a volume could get around enough on its own steam in the last 5 years to make the impression that plastics have already made; the explanation is that the most important applications of plastics have been in combination with their bigger brothers, the metals.



1. AN EXCELLENT EXAMPLE OF METALS-AND-PLASTICS COLLABORATION IS THIS PORTABLE INDICATING COMPARATOR.

The handle is injection-molded of Teutite plastic, whose low thermal conductivity prevents the heat of the operator's hand from affecting the precision of the metal measuring components. Courtesy Tennessee Eastman Corp.)



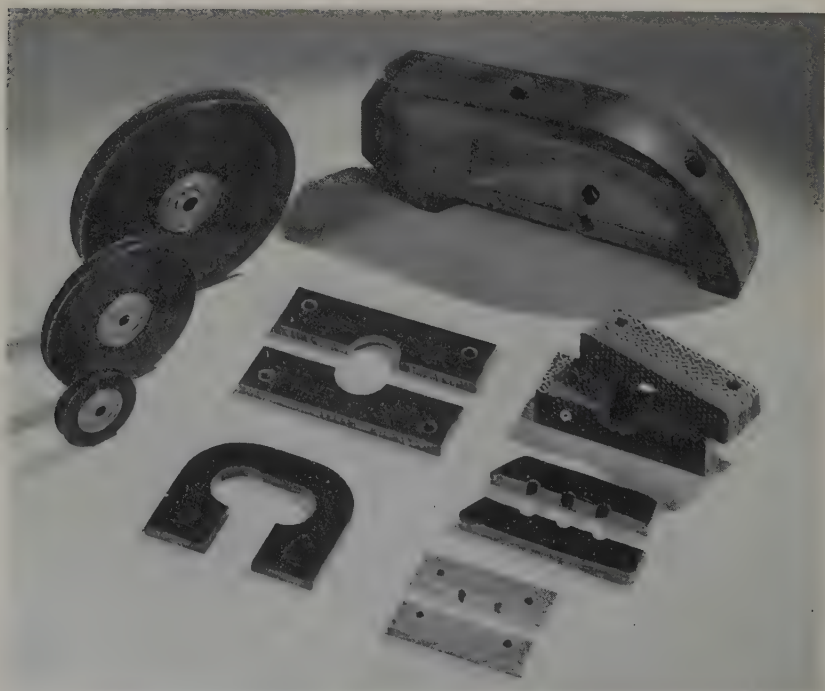
2. PREGWOOD—RESIN-FUSED WOOD LAMINATIONS—COMES CLOSER TO THE METALS IN TENSILE STRENGTH THAN THE OTHER PLASTICS.

When made into propellers the material is combined with metal edges to improve service life. (Courtesy Formica Insulation Co.)



1. INJECTION-MOLDED FIBESTOS PLASTICS PARTS ARE COMBINED WITH METALS IN THIS TANK WINDSHIELD ASSEMBLY.

(Courtesy Monsanto Chemical Co., Plastics Division.)



2. THESE AIRCRAFT PULLEYS, FAIRLEADS, PROPELLER SUPPORTS, AND CABIN AIR CONTROLS ARE FABRICATED FROM LAMINATED PLASTICS.

(Courtesy Bakelite Corp.)

THE MINERAL POSITION OF THE UNITED STATES AND THE OUTLOOK FOR THE FUTURE¹

BY ELMER W. PEHRSON

Chief, Economics and Statistics Branch, Bureau of Mines

The experience of the past 5 years again has awakened the national conscience to the importance of our mineral resources. The devastating effectiveness of modern weapons made from metal and propelled by mineral fuels, the mineral shortages that have at times threatened serious repercussions on the battle front, the scarcity of the modern conveniences to which we have become accustomed, and fuel and gasoline rationing have brought home with emphasis the tremendous importance of minerals in modern life. Without its mineral resources the United States would be restricted to an agricultural-type economy capable of supporting considerably less than the 135,000,000 people now living within its borders at a standard that is the envy of the world. These same resources permit the 7 percent of the world's population residing in the United States to do 40 percent of the world's work. The fact is that we owe our industrial and military power to our great mineral resources, the equal of which has not yet been developed in any other like area of the globe.

Possession of such wealth is of course an outstanding national asset, but it is one that also could have serious implications for the future. This arises from the fact that unfortunately mineral deposits are exhaustible, from which it follows that the faster we grow in industrial strength and military potency—a growth made possible largely through increased mineral output—the faster we liquidate the very basis of our power. That power must be sustained not only to assure our economic well-being but also to permit us to discharge effectively the greater responsibility in international affairs that will come to us in the postwar years. It is in keeping with the times, therefore, if tonight we endeavor to appraise our present mineral position and explore the outlook for the future, and, in view of the epochal decade in world affairs that lies ahead, it is essential that we do this with realism and candor.

¹ Presented before the New York Section, American Institute of Mining and Metallurgical Engineers, February 19, 1945. Published by permission of the Director, U. S. Bureau of Mines. Reprinted by permission from *Mining and Metallurgy*, April 1945.

There has been considerable public discussion of late that indicates a wide divergence of opinion as to where we stand with respect to future mineral supply. From some quarters we hear that the United States is about to become a "have-not" nation and about to experience the evil consequences such a situation would entail. Others claim that we are still a treasure house of stored-up mineral wealth, the surface of which barely has been scratched. It is believed that the data to be presented this evening support the conclusion that neither

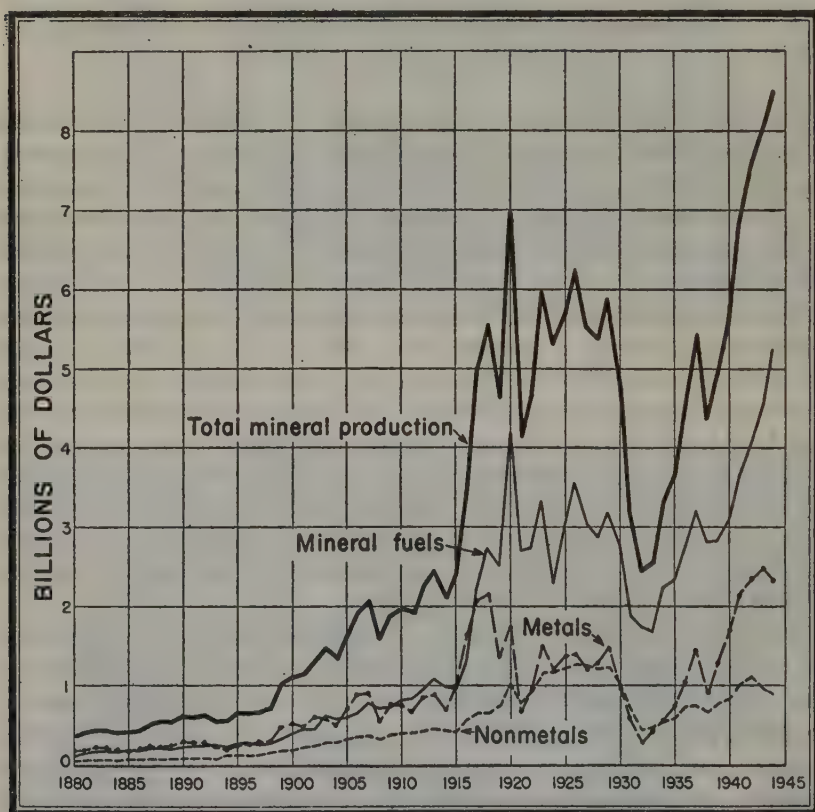


FIGURE 1.—Trends in value of mineral production in the United States, 1880–1944.

of these viewpoints is correct and that we are far from exhaustion of those mineral resources that are basic to our industrial economy. However, exhaustion is well advanced in a number of important subsidiary minerals so that we can no longer drift along with the easy-going philosophy that the earth will provide. The time has come when we must recognize the true situation and do something about it.

EXPANSION OF MINERAL PRODUCTION RAPID

The vigorous manner in which the United States has forced the earth to yield its mineral treasure is attested by figure 1, which shows

the growth of mineral production from 1880 to 1944. During this period the annual output rose from less than one-half billion dollars to eight and one-half billion, a sixteenfold increase. During the first two decades of this period there was a relatively slow rise in production, but with the turn of the century a rapid advance set in which was further stimulated by World War I and the succeeding boom period. Since 1900 mineral production in the United States has exceeded that of the entire world prior to that time. This period terminated with the collapse in the latter part of 1929 following which there was a precipitous decline to 1932 and a substantial recovery thereafter which was carried to an all-time record production in 1944 by the war. It will be noted that since 1915 the production of mineral fuels has achieved outstanding significance, this being due largely to the rapid rise in petroleum production and the accompanying growth of automotive transportation. Metals have ranked second in importance in recent years, with the nonmetals other than fuels holding third place. The importance of metals in war is clearly indicated by the peaks experienced in both war periods.

Aside from these direct contributions to the national income, the mineral industries have employed hundreds of thousands of workers. In 1900 it is estimated that 500,000 persons were gainfully employed only in the extraction of minerals. By 1923 employment had reached a peak of 1,080,000, following which there was a decline to about 660,000 in 1943. Increasing mechanization and other improvements in mineral technology have greatly increased the output per worker so that compared with 1923 it was possible in 1944 to obtain a third more output measured quantitatively, with a third less workers. The processing of minerals and the services required by the mineral industries give employment to several hundred thousand more workers.

Figure 2 compares the growth of the physical volume of mineral production with that of agricultural and industrial production and population from 1900 to 1944. It will be noted that prior to 1940 mineral output and industrial production were closely correlated and increasing faster than the growth in population. Expansion in agricultural production, on the other hand, more nearly approximated the population trend. Since 1940 there has been great disparity between the mineral and industrial trend lines. This is due to several factors, among which are the greater use of imported minerals, which is reflected in the industrial indexes, but not in the mineral indexes used in constructing the chart, and in part by the fact that the mineral index does not include certain commodities such as aluminum and magnesium, production of which has increased greatly during the war.

Figure 3, which shows the dollar value of imports and exports of minerals and mineral products, indicates that we have been generous in making our minerals available to the rest of the world. Foreign trade figures include some semifabricated products the dollar value

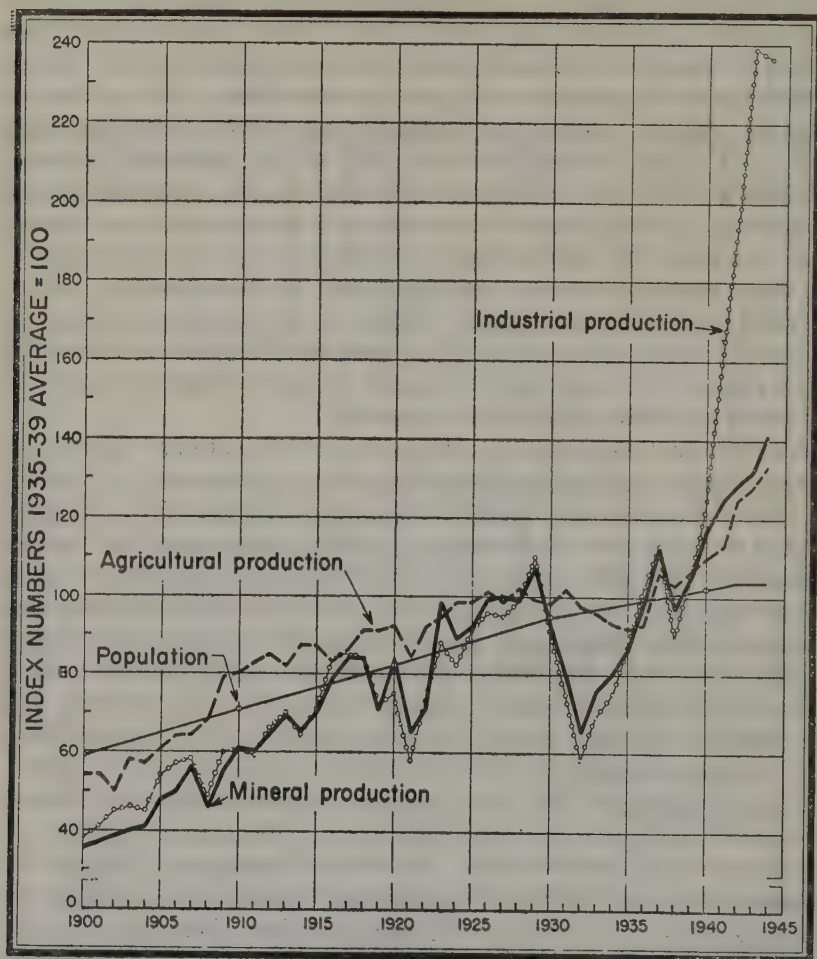


FIGURE 2.—Comparison of growth of physical volume of mineral production with that of agricultural and industrial production and population, 1900-44.

of which per unit of mineral is relatively high compared with that of raw materials. The values shown in the chart, therefore, are not directly comparable with those given for mineral production.

NEED FOR APPRAISAL OF MINERAL RESERVES

The unprecedented rate at which we have been depleting our mineral resources and the difficulties encountered in obtaining sufficient

minerals to sustain the war program have focused attention on the need for reviewing and clarifying national mineral policy. This in turn has indicated the need for an appraisal of reserves, for such data obviously are a prerequisite to an understanding of the mineral problem. As a contribution to this objective the Geological Survey and the Bureau of Mines began a study of available information on mineral deposits with a view to preparing estimates of national reserves. This work has been under way for over a year and an initial report will be completed shortly. I am indebted to Dr. W. E. Wrather, Director of the United States Geological Survey, and Dr. R. R. Sayers, Director of the United States Bureau of Mines, for permission to use

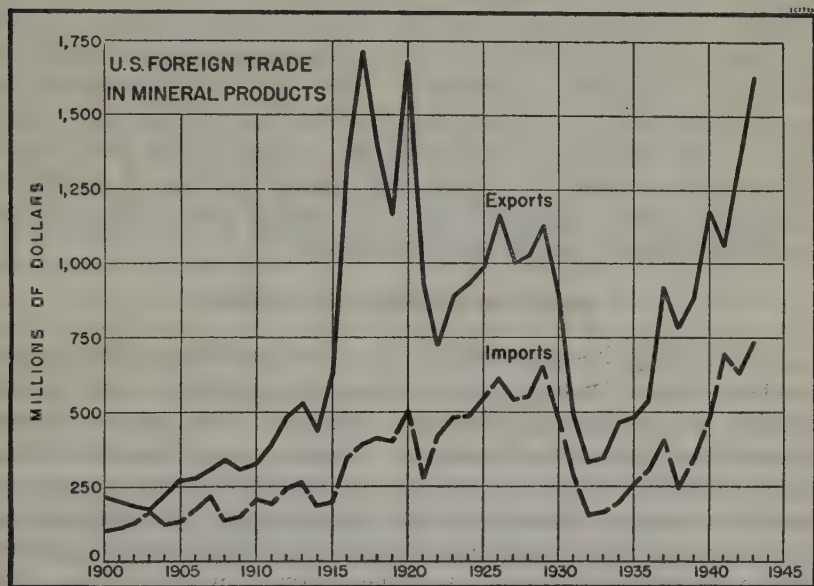


FIGURE 3.—Value of United States imports and exports of minerals and mineral products exclusive of advanced manufactures, 1900–43.

a preliminary summary of the study. The estimates were prepared by geologists and mining engineers in the two Bureaus, and to them must go full credit for the results that have been obtained. Those of you who have struggled with the problem of evaluating the reserves of a single mine can readily appreciate the problems involved in appraising the reserves of the entire country. The Geological Survey, since its creation in 1880, and the Bureau of Mines, since 1910, have been gathering information on our mineral industries, and following the passage of the Strategic Materials Act in 1939 there has been extensive activity in exploring deposits of "strategic" minerals. The analysis of these data and the preparation of the estimates have required much painstaking research and careful analysis as well as

the exercise of sound and objective judgment. While acknowledging this outstanding contribution of my colleagues, I must absolve them of any responsibility for the comments herewith as to the national significance of the estimates, as these represent largely my own views.

It would be easy to avoid the responsibility of estimating national mineral reserves on the grounds that there are so many unpredictable and unforeseen factors involved in the occurrence and discovery of mineral deposits that it is futile to be specific on a quantitative basis. However, despite the limitations in estimates of this kind, I believe it is helpful to have well-informed men make available their opinions on the magnitude of our reserves as such information provides a practical basis for discussion. Moreover, many basic decisions on national policy will have to be made by our leaders within the next few years, and those decisions can be made more wisely if the objective judgment of experts is available. The data to be presented this evening represent only the highlights of the reports prepared by these men. They should be used with the understanding that reserve estimates are subject to change even under the best of conditions, particularly when attempted on such a broad scale. The estimates therefore represent preliminary figures only.

BASIS OF RESERVE ESTIMATES

In attempting this appraisal of our mineral position major emphasis has been placed on those reserves that are available under present economic conditions and technologic practices. They may be referred to broadly as "commercial" reserves. Future supply-demand relationships and prices as well as progress in mineral technology are not susceptible to precise determinations. Consequently the economic and technical factors involved in estimates of commercial reserves, in addition to the geological factors, must be analyzed in broad terms. The data available do not permit detailed estimates within various narrow price ranges. In general, the estimates may be considered as representing reserves available at good prewar prices, although some of them are predicated on moderately higher prices.

Company reports and other public statements on mineral reserves frequently include only such quantities as are practically assured on the basis of engineering data. They, therefore, present an extremely conservative appraisal of potential mineral supplies and are apt to be misleading if they are not used in proper perspective. To present a more realistic picture of our mineral potential, the Survey-Bureau specialists have for most commodities evaluated commercial reserves on the basis of measured, indicated, and inferred ore, using the official definitions that have been established for these categories. Notable

exceptions are petroleum and natural gas, for which it was felt that available data did not permit estimates of inferred reserves with any acceptable degree of accuracy.

UNCERTAINTY OF FUTURE DISCOVERIES

In appraising the significance of present estimates of commercial mineral reserves, consideration must be given to the possibilities of discovery not contemplated in the inferred ore included in the estimates. We may start with the assumption that the potential mineral areas of the Nation have been heavily prospected and most of the surface deposits or those whose presence is indicated by superficial phenomena already have been found. This assumption is substantiated by the decline in new discoveries. During the past 2 years, much attention has been given to the failure of petroleum discoveries to keep pace with the rapid rate of depletion. The rate of discovery of metalliferous deposits has been declining at an alarming rate for half a century. It is significant to note that no major metal-producing district comparable to Butte, Bisbee, Homestake, or the Coeur d'Alene has been brought into production in the United States since the active development of the Picher-Miami lead-zinc deposits of the Tri-State area about 1916. There have been few important copper discoveries in the present century. Most of the large deposits producing today were known before 1900. The largest discovery since then has been the United Verde Extension mine at Jerome, Ariz. The production from this property was relatively insignificant in terms of national needs, the entire output in the 20-odd years the mine operated having amounted to only a half-year supply at normal rates of consumption. It is true that new mines have been developed, but the large ones were the result of the application of improved technology to deposits whose presence had been known for many years, and the small ones in the aggregate contribute but a small part of the national requirements. Future additions to the national reserve will depend largely on the success achieved in utilizing known low-grade deposits not available economically at present and the discovery of deep-seated or concealed deposits, the presence of which is not easily discerned. Progress in converting submarginal resources into commercial reserves can be made through research to improve methods of extracting and processing minerals and to reduce costs. Higher prices also can be an important contributing factor.

Progress in the field of new discovery depends upon the success attained in developing effective and economical methods for finding deposits not recognizable from surface indications alone. Substantial quantities of ore occurring under heavy cover have been found by

underground exploration conducted in active mining areas, and geophysical methods guided by intelligent, detailed geologic advice have been very successful in locating petroleum deposits. Further development of concealed resources by a combination of these methods is anticipated but the days of easy and accidental discovery are about over. Prospecting by geophysical methods is costly, and as the old mines play out, underground prospecting ceases in the well-established producing districts. Additions to known or inferred reserves of most minerals, therefore, depend on technologic progress and the success of exploration that is carefully planned and scientifically executed.

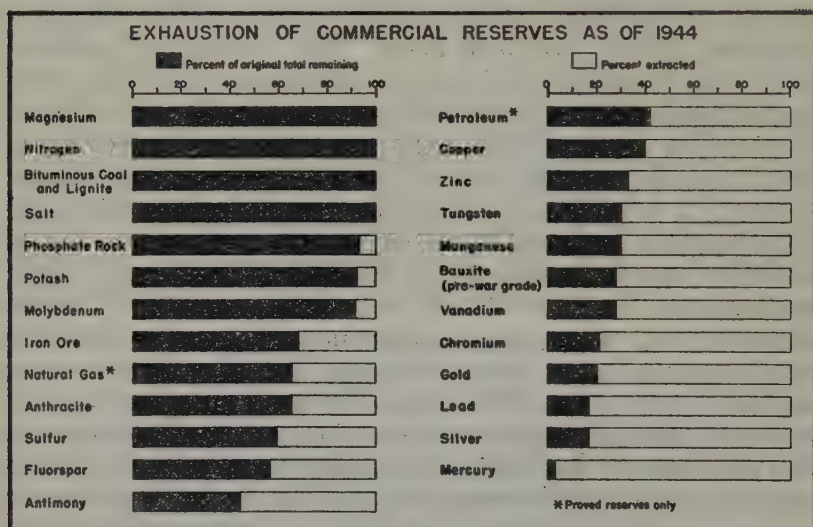


FIGURE 4.—Chart showing proportion of estimated original commercial reserves (measured, indicated, and inferred) of certain minerals in the United States remaining as of 1944.

The effects of these programs on our mineral reserves obviously cannot be evaluated with assurance at this time and opinion varies widely as to the probable outcome. New deposits undoubtedly will be found as will extensions to known ore bodies not contemplated in present estimates of inferred ore. In general, however, I am inclined to believe that the risks and costs involved are too great to warrant the assumption that our present estimates will be increased greatly through future discovery. In any event, it is evident that the outlook does not justify determination of national policies solely on the expectation of large additions to our commercial reserves through the discovery of new deposits.

RESERVES COMPARED WITH PAST PRODUCTION

To indicate the approximate degree of exhaustion that has occurred to date the estimates of remaining reserves are compared in figure 4

with the original reserve, which was determined by adding the total production through 1943 to the reserve estimates as of January 1, 1944. The chart includes 25 of the major industrial minerals for which reasonably reliable estimates can be made. It does not include building materials, with which the United States is amply supplied, nor does it include some important minerals of which the United States is notably deficient, such as tin and nickel.

Outstanding features of the chart are the relatively favorable position in coal and the fertilizer materials, and the relatively depleted state of our metallic reserves. There has been no exhaustion of the original reserve of magnesium and nitrogen, the supplies of which are virtually inexhaustible, because of the abundance of brines and ocean water from which we obtain magnesium, and of air from which we extract nitrogen and other valuable elements. Air and water are two minerals whose importance should not be overlooked although, of course, they present no reserve problem. At the other extreme is mercury, of which it is estimated that only 3 percent of the original commercial reserve remains. This metal presents an interesting illustration of the relation of production and price. Production reached a peak as far back as 1877, when the United States was supplying most of the world. Since the last war we have been heavy importers yet the stimulus of high war prices—over four times those of 1877—has brought forth a surprisingly large output in the last few years. The percentages shown for natural gas and petroleum are based on proved reserves only, which tends to exaggerate the depletion that has taken place in these industries. The exhaustion indicated for antimony, manganese, and chromium are of nominal significance only in view of the fact that domestic resources have not made important contributions to national requirements as will be shown later. Somewhat more significant is the situation shown for tungsten, vanadium, and bauxite, although we also have been large importers of these materials in the past. The position of iron ore is a matter of some concern from the long-range view because of its essentiality to our industrial structure. Of more immediate concern is the depleted state of our copper, lead, and zinc resources and it is also apparent that we have drawn extensively on our commercial reserves of gold and silver.

RESERVES COMPARED WITH PREWAR CONSUMPTION

Figure 5 shows the estimated commercial reserves of various minerals in terms of years' supply at the average annual rate of consumption from 1935 to 1939. The data should not be interpreted as indicating that production large enough to meet the prewar rate of use could be sustained for the periods indicated. Many of the minerals shown are not now being produced in quantities equal to domestic

requirements, and as depletion progresses the maximum or optimum rate of production declines for reasons that need not be discussed here. The availability of those minerals that are essentially byproducts, such as antimony and silver, is further restricted by economic and technologic factors that control the rate of production of the other minerals with which they are associated. Nine of the 33 minerals shown on the chart are available in quantities equivalent to more than a 100-year supply at the prewar rate of use. Only four fall within the 25-to-100-year supply bracket, while eight qualify in the 5-to-25-year group. The reserves of the remaining 12 are small, representing

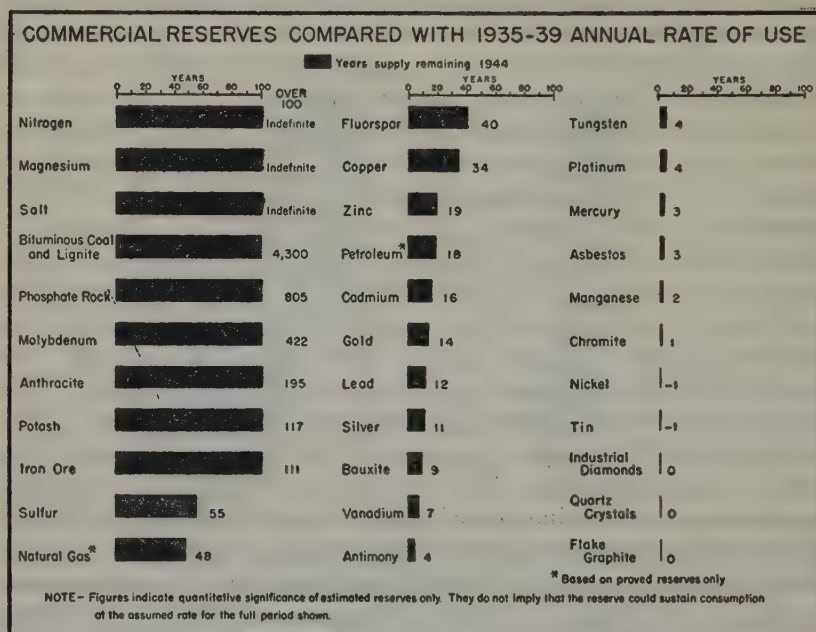


FIGURE 5.—Commercial reserves of certain minerals as of 1944 expressed in terms of years life at average annual rate of consumption 1935-39.

less than a 5-year supply. The significant point is that if we make a division at the 35-year level, a period but little more than the usual interval between wars, 21 of the 33 minerals fall below the line, and this group includes petroleum, copper, lead, and zinc in the production of which we have led the world for many years.

The rate of production the remaining reserves can support in the future is no less important than the size of the reserve. Production of those minerals of which we have over a 100-year reserve could be expanded to meet any demand that can reasonably be expected. Moderate expansion of postwar production of sulfur, fluorspar, and natural gas over prewar peak rates doubtless could be accomplished if justified by economic conditions. It is doubtful if copper production could be

expanded much over present rates and a decline is anticipated in a decade. The production of petroleum already is reported to have reached or exceeded optimum rates and any increase in output at this time would be at the expense of efficient recovery. For the remaining minerals shown on the chart decreasing rates are likely within a relatively few years.

SUBMARGINAL RESOURCES

The foregoing analysis indicates that some of our "blue chip" mineral resources have been depleted to a critical point. This raises a question as to the possibilities of developing our submarginal resources, the order of magnitude of which is shown in figure 6. In this chart

ORDER OF MAGNITUDE OF SUBMARGINAL AND HIGHLY SPECULATIVE RESOURCES				
Supply based on average annual rate of consumption from 1935-39				
OVER 500 YEARS	100 TO 500 YEARS	25 TO 100 YEARS	5 TO 25 YEARS	LESS THAN 5 YEARS
Iron Ore	Bauxite	Flake Graphite	Asbestos	Antimony
Magnesium	Manganese	Petroleum	Cadmium	Industrial Diamonds
Nitrogen	Molybdenum		Copper	Lead
Phosphate Rock	Vanadium		Chromite	Platinum
Potash			Fluorspar	Quartz Crystals
Salt			Gold	Tin
Sulfur			Mercury	
			Mica (black)	
			Nickel	
			Silver	
			Tungsten	
			Zinc	

NOTE - The availability of these resources is highly speculative or remote because of uncertainties in basic estimates, high costs of recovery, or technologic problems involved in their utilization. They do not include commercial reserves.

FIGURE 6.—Rough quantitative appraisal of submarginal and highly speculative mineral resources in the United States as of 1944.

an attempt has been made to show the years-supply equivalent of submarginal and highly speculative resources. The availability of these resources varies considerably but on the whole is remote because of uncertainties in basic estimates, high costs of recovery, or technologic problems involved in their utilization. Although they represent a substantial potential national asset and offer a fertile field for research most of them must be considered as largely unavailable under any economic conditions that can be anticipated, at least in the next quarter century.

Comparison of this list with figure 5 reveals that with few notable exceptions submarginal reserves are roughly proportionate to commercial reserves. No estimates of submarginal resources of coal are available, but in view of the large known quantities of commercial coal, such estimates would be of academic interest only. Noncom-

mercial resources of nitrogen, magnesium, and salt for practical purposes may be regarded as limitless and also of academic interest at this time. Potential reserves of phosphate rock, molybdenum, potash, iron ore, and all forms of sulfur are significant because they assure ample supplies of these important raw materials for many years to come if we are willing to pay the price for them. The large submarginal resources of bauxite, manganese, and vanadium afford a measure of safety against possible shortages of these strategic materials in future emergencies and eventually may even provide peacetime industries. The bauxite in this category is largely high-silica and high-iron ore that cannot compete with high-grade foreign ores. In addition to this off-grade bauxite there are large quantities of other minerals to supplement our submarginal resources of raw materials for the production of aluminum. Flake graphite is available in fairly large quantities but it is of low quality compared with foreign materials. Its use would be costly and the products made from it inferior. The position of petroleum on the chart is based on the statement of Wallace E. Pratt that the ultimate production of the United States should total at least 100 billion barrels. Obviously this must be regarded as highly speculative. From the long-range view, the submarginal resources of the other minerals appear to offer only moderate expectations of an improved reserve position in the future. This group includes such important materials as copper, lead, zinc, tin, nickel, and chromite.

Because of the many uncertain factors involved and the limited information available on submarginal resources, the foregoing conclusions must be regarded only as a very rough indication of the possibilities that are apparent at this time.

OUTLOOK FOR THE FUTURE

With this appraisal of our mineral resources in mind we may explore the outlook for the future in more detail. Coal is the priceless ingredient that protects the industrial health of the Nation; it is the Nation's number one asset, although our agricultural friends might dispute this assertion. Iron ore certainly ranks second among the minerals, and because of the widespread use of the internal combustion engine we must accord petroleum third place. These three minerals being of outstanding importance merit special consideration.

Coal.—The five great centers of industrial and military power have developed around large coal resources. The United States, England, Russia, Japan, and Western Europe are the principal coal-producing regions of the world and owe their position in world affairs largely to that fact. Coal is essential in the production of steel and mechanical power and these are the primary requirements for industrial develop-

ment. The United States is fortunate in having the largest reserve in the world, but the tremendous contribution of coal to the Nation's welfare is too little appreciated by the public, which is prone to regard the coal industry as an occasional source of annoying labor-management disputes and disagreeable fuel shortages. We have no serious difficulties of supply in sight, although the reserves of high-grade coking coals are none too plentiful and may present some problem in the not-too-distant future. Our disposition to take coal for granted because of the magnitude of the reserves is illustrated by the fact that little reliable information is available on our coking-coal reserves despite the fundamental importance of the commodity. The same apathy confronts the conservationist who views with alarm the 30- to 40-percent average loss of coal sustained in mining. Some of this loss is unavoidable, but much could be prevented if economic conditions in the industry permitted. Conservation can also be promoted through further progress in the technology of coal use, and some have questioned the wisdom from a national viewpoint of consuming limited reserves of high-grade coking coals in noncoke uses. If we are to turn to our coal resources for liquid fuels in the future, the rate of exhaustion probably will more than treble, and the need for conservation will be correspondingly greater.

While we have used up a substantial part of our anthracite, our basic position in coal is outstandingly good, although it would seem that a wiser Nation would use its reserves a little more prudently even though the day of reckoning on shortages is centuries away.

Iron ore.—Iron ore ranks second to coal in national importance only because experience indicates that steel-making slightly favors the coal areas. Four of the five great centers of industrial power have outstanding iron resources. Japan is notably deficient and has attempted to overcome this weakness through aggression and commercial expansion. The United States is well supplied with iron ore, although the reserves do not match those of coal by a wide margin. It is estimated by Ernest F. Burchard of the Geological Survey and Albin C. Johnson of the Bureau of Mines that the reserves of iron ore of present commercial or usable grade total 5,478,000,000 long tons, of which about a third is classed as inferred ore. Total production through 1943 was 2,613,000,000 tons so that 68 percent of the original reserve, based on present estimates, still remains. Opinions differ as to the price at which this ore is available but it is believed that it can safely be assumed that virtually all of it could be mined at prices that have prevailed in the past or at moderately higher prices. In addition to this commercial reserve there is a potential reserve of 63,000,000,000 tons of submarginal ore, the utilization of which will depend on technologic advances and economic conditions.

Figure 7 shows the geography of the reserves, production, and consumption of iron ore. The importance of the Lake Superior district as a source of supply is obvious. Its proportion of commercial reserves, however, is considerably less than its share of current production, which fact indicates that the relatively more favorable reserve position in the southeastern and northeastern regions will bring forth a somewhat larger proportion of production in those areas in the years to come. The concentration of iron-ore consumption in the States bordering the Great Lakes may be expected to continue with minor modifications for many years. The steel industry in this region is soundly based on the proximity of coal and iron ore and a tremen-

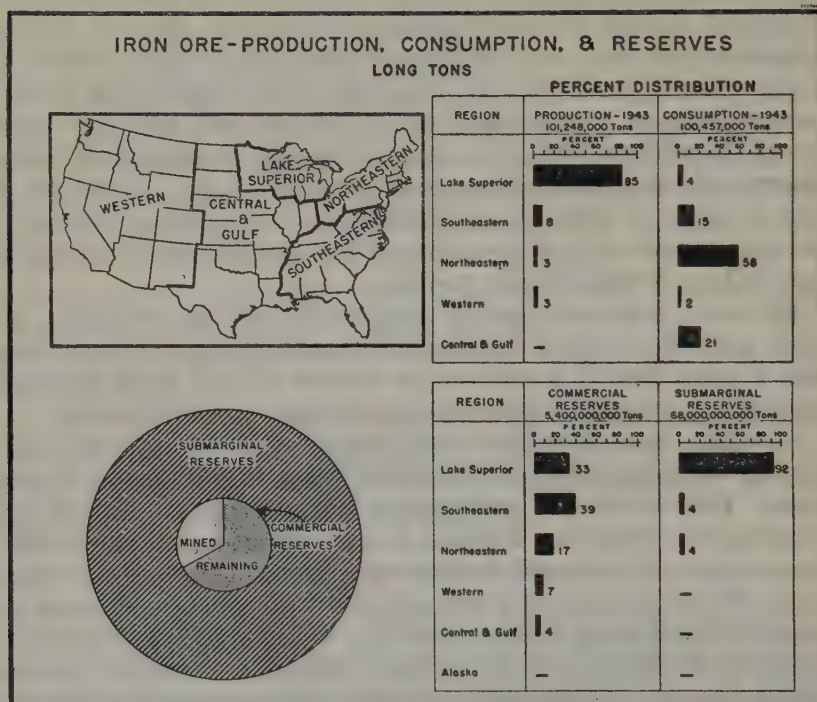


FIGURE 7.—Geography of iron-ore production, consumption, and reserves.

dous consuming industry has been built around it. Further development of northeastern iron ores will cause little if any change in the geography of steel production. Moderate expansion on the seaboard seems probable. The expansion that may result from the favorable reserve position of the southeastern States and the postwar operation of the new plants in the West will have only limited effects on the present pattern of steel production. The situation in the more distant future will depend on national policies which probably will be determined by the success achieved in developing the low-grade ores of

Minnesota. It seems probable that the huge iron-ore resources of that region will continue to be the outstanding source of iron ore for the steel industry of the United States.

Figure 8 shows the past production of pig iron and iron ore and an appraisal of the possibilities during the next quarter century. The forecasts for 1970 were based on an analysis of the probable demand for steel assuming that per-capita consumption in 1970 might lie between 0.60 and 0.73 short tons. These represent increases of approximately 25 and 50 percent over the predepression rate of 0.48 tons. With a population of 156,549,000 in 1970 steel requirements would

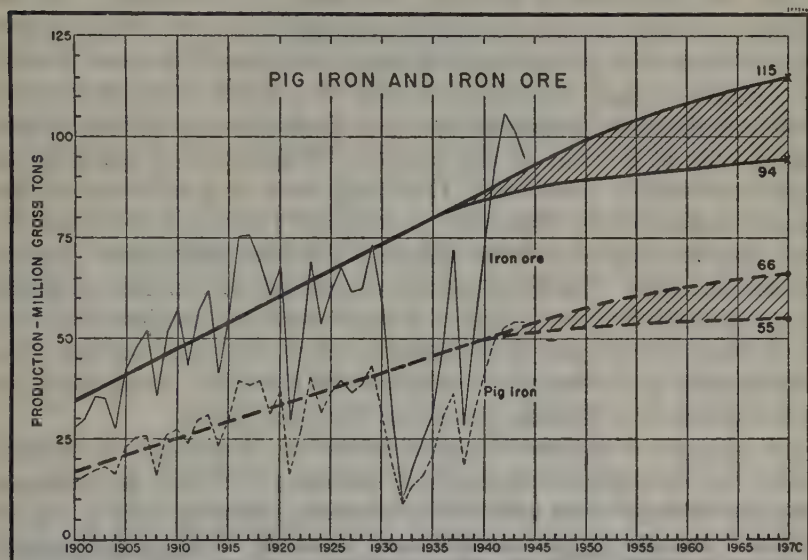


FIGURE 8.—Production of iron ore and pig iron in the United States, 1900 to 1944, and estimated range of production to 1970.

be between 94,000,000 and 115,000,000 short tons, the lower figure appearing to be the most acceptable estimate. At the normal operating rate of 75 percent of capacity, plant requirements would be between 125,000,000 and 150,000,000 tons. The present installed capacity is 93,500,000 tons.

Pig-iron requirements in 1970 were computed on the assumption that there would be a slight increase in the use of scrap and a corresponding decrease in the ratio of pig iron to steel. The latter was estimated at 65 percent in 1970 compared with 68 percent during the past decade. On this basis pig-iron requirements in 1970 would be between 61,000,000 and 74,500,000 short tons. The present capacity is 67,500,000 tons according to the American Iron and Steel Institute.

During the past 10 years the ratio of iron-ore production to pig-iron production has been 1.72 to 1. Assuming this ratio will continue and

that imports will remain at the same proportion as in the past, the iron-ore requirements in 1970 total between 95,000,000 and 115,000,000 long tons. Maximum production to date was 105,526,000 tons in 1942.

While the total iron-ore reserves appear to be ample to meet domestic requirements for a prolonged period, we shall soon be confronted with a major problem because of the exhaustion of the direct-shipping ores of the Lake Superior district, found chiefly in the Mesabi Range in Minnesota. This ore represents the cream of our resources because the deposits can be mined cheaply and the ore used directly in the blast furnace without prior treatment. Direct-shipping ores of Minnesota account for 50 percent of the total production of the country. At the 1942 rate of extraction the remaining tonnage represents only 17-years' life, and the rate of production will begin to decline in the near future. The problem is made more acute because 90 percent of the production of these high-grade Minnesota ores come from the open-pit mines that contain only 57 percent of the reserves. Exhaustion of these mines is therefore rather imminent. Declining rates of production at the open-pit mines can be offset only in part and for only a few years by increasing the output of direct-shipping ore from underground mines and concentrates. The total estimated reserves of commercial-grade ore in the Lake Superior district is equivalent to less than 25-years' life at the current rates of production. It is therefore obvious that if the district is to continue to supply large tonnages, development of the low-grade ores must be started in the near future.

The open-pit mines provide great flexibility in production because mining can be stopped completely if necessary with low maintenance costs and little adverse effect on production capacity, and it can be increased quickly in periods of heavy demand. During the present war this resource has been of inestimable value in making possible our enormous steel output. The impending loss of this facility is thus a matter of major national interest because it has served as a gigantic stock pile which has supplied the needs of the Nation in times of heavy demand and national emergencies. If we are to become dependent on our lower-grade ores we shall have to build large plants to treat them. Such plants provide rigid limits on production capacity and if surplus capacity is maintained to meet peak demand, depreciation and obsolescence on a large scale will have to be reckoned with.

Failure to develop the low-grade ores of the Lake Superior district eventually would lead to dependence on foreign sources of supply. In view of the large tonnages required, the maintenance of shipments from foreign sources in time of war would present a major problem of national defense. Because of this and the high essentiality of steel in war, it would seem unwise for the United States to allow its self-sufficiency in iron ore to fall to dangerous limits. Presumably to maintain our present position would justify some extra cost to the

public, but the consumer cannot be expected to assume an unreasonable burden on this account.

Our position in iron ore presents a problem for the near future, but it is confidently expected that American ingenuity and enterprise will solve it in a satisfactory manner.

Petroleum.—To forecast future trends in domestic production and consumption of petroleum taxes the ability of the most ambitious crystal-gazers. The difficulty arises in trying to reconcile the extraordinary growth of this industry with the relatively limited reserves reported to be available. The American Petroleum Institute estimates known or proved reserves at approximately 20 billion barrels. Last year we produced 1.7 billion barrels of crude oil so that the reserve is equivalent to about a 12-year supply at the 1944 rate of extraction. Most experts anticipate the discovery of more oil, but few of them venture a guess as to how much or at what rate. Wallace E. Pratt's estimate of an ultimate yield of at least 100 billion barrels already has been mentioned. On this basis we have a total speculative reserve of 70 billion; 30 billion barrels have been produced to date. Even this quantity of oil, however, provides only about a 40-year supply. Fortunately our chemical brethren have devised methods of making petroleum products from abundantly available raw materials so that in the long run we need not worry about shortages. For the time being, however, your daily newspaper gives evidence that current supplies are far from ample to meet all demands although all military and essential industrial and civilian needs are being met.

I shall not discuss the present situation other than to call attention to the concern expressed by some authorities over the declining rate of discovery. In discussing this problem in a hearing on synthetic liquid fuels conducted by a Subcommittee of the Senate Committee on Public Lands and Surveys in August 1943, William B. Heroy, then Director of Reserves for the Petroleum Administration for War, presented an analysis of discovery experience from 1936 to 1942. During this period, despite increased geophysical work and wildcat drilling by the industry, the number of new fields reported increased from 162 to 348 but the total estimated proved and possible new reserves discovered declined over 75 percent; the quantity per field declined from 14.8 million to 1.5 million barrels. In the latter year crude oil production averaged 3.8 million barrels per day. After pointing out that there were divergent opinions on the outlook for future discoveries, Heroy stated that, in his opinion, the facts did not warrant a defeatist attitude, but that the public and the industry should realize the bonanza days of oil discovery, for the most part, belong to history.

Unless there is improvement in the rate of discovery, it would appear that production may be expected to decline in the near future.

Against this is the ever-increasing demand for petroleum. The per-capita consumption has increased from less than half a barrel in 1900 to 12.1 barrels in 1944, with the upward trend continuing at a rapid rate. No prediction of future trends can be made with assurance because of the uncertainty as to various pertinent factors. It is believed in some quarters that the use of automobiles was approaching saturation before the war, and that the increase in per-capita consumption of motor fuel should taper off. This use normally accounts for about 45 percent of the oil consumed, the remainder being used largely for heating purposes. Higher prices that would most certainly result from a decline in crude-petroleum supplies would have pronounced effects on the use of oil for heating and might influence the market for motor fuels. The expectation of a sharp falling-off in the rate of increase in per-capita consumption seems reasonable in the near future but its quantitative significance cannot be appraised. At the 1944 rate oil demands in 1970 with the anticipated 13 percent increase in population would be 1.9 billion barrels. This would seem to be a minimum expectation.

Presently known petroleum reserves would not permit production to meet even the minimum demand 25 years hence. Thus if future discoveries fail to remedy the situation we are faced with the need for developing supplemental sources of supply. Under peacetime conditions substantial quantities of oil could be obtained from the Caribbean area and if necessary from more distant sources. This would seem to be the most economical solution of the problem. If for any reason foreign supplies were unavailable we can turn to other domestic sources. Secondary recovery from depleted oil structures has begun already and could be increased considerably at higher prices. Synthetic liquid fuels offer a feasible though more costly solution. For this purpose natural gas offers the cheapest source of these products for the immediate future, but the supply is relatively small. Tar sands, oil shale, and coal (including lignite), also are available, and in the aggregate represent an enormous reserve. The largest though not necessarily the lowest cost source of synthetic liquid fuels is coal. According to Dr. A. C. Fieldner, Chief of the Fuels and Explosives Branch of the Bureau of Mines, synthetic motor fuel can probably be made from coal at 18 cents per gallon in large plants under normal conditions. He believes that costs of 12 to 15 cents are possible after industry has fully developed the techniques. Present costs of producing gasoline from crude petroleum are approximately 5 cents per gallon.

The higher costs of synthetic petroleum products doubtless will necessitate many changes in industries now using the natural oils. This together with the public need for low-cost gasoline probably will cause a shift to imported petroleum in advance of large-scale

development of synthetic fuels if our domestic petroleum reserves fail. As with iron ore, large-scale dependence on foreign sources for such a strategic commodity is objectionable from the standpoint of national defense. Insurance against shortages in future emergencies could be provided by setting aside proved oil fields as a national petroleum reserve. The minimum requirement in the event of a decline in domestic oil production is the establishment and maintenance of a synthetic fuel industry of sufficient size to provide a nucleus of proved

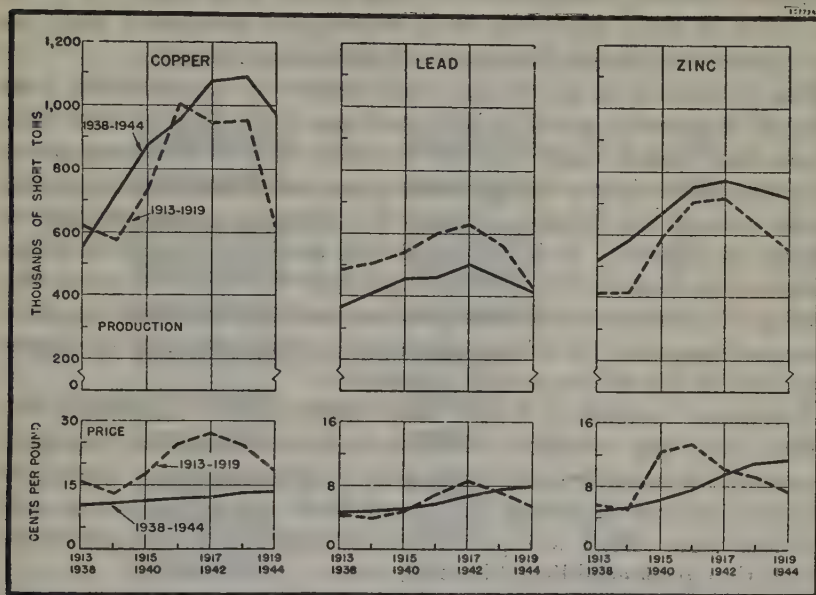


FIGURE 9.—Comparison of mine production and prices of copper, lead, and zinc in the United States during World War I and World War II.

technology and experienced personnel which could be expanded in an emergency. Congress has taken the initial step in this direction by authorizing the Bureau of Mines to establish large demonstration plants for the production of synthetic liquid fuels.

Our position in petroleum may be summarized as uncertain with moderate dependence on imports a distinct possibility in the near future. This need not be regarded as threatening to the national security because feasible measures can be taken to provide against future shortages in time of war.

Copper, lead, and zinc occupy a significant position among the minerals of secondary importance to the basic national economy. The United States has had virtual self-sufficiency in these metals for many years. However, our resources were unequal to the demands of this war and large imports have been required in recent years. Figure 9

compares prices and mine production of copper, lead, and zinc during the two World War periods. Despite the fact that the demand has been very much larger in World War II, the output of copper and zinc has been only moderately higher and that of lead substantially lower than in World War I. This record can be ascribed in part to various causes such as manpower and equipment shortages, the fact that the industries had not fully recovered from a protracted depression, and insufficient price; but there is wide agreement that the ore-reserve situation was the principal contributing cause. That depletion is well advanced in these industries is an inescapable conclusion from the record and the present knowledge of remaining reserves.

Copper reserves as of 1944 have been estimated ² at 20,000,000 short tons of recoverable metal under conditions prevailing at that time. Since they include some reserves available only at premium prices they may be considered as a generous appraisal of commercial reserves under normal conditions. Twenty-five percent of the tonnage is classed as inferred. It is estimated that production could be maintained at the rate of 1,000,000 tons per year for nearly 10 years following which there would be a gradual decline to exhaustion. Submarginal resources have been estimated at 10,000,000 tons of copper contained in 1.25 billion tons of material.

Estimated reserves of 6-cent lead ³ under prewar operating conditions were only 5,000,000 short tons in 1944, of which only a third was classed as measured and indicated. Under emergency conditions the total reserve including the 6-cent lead, was estimated at only 6,600,000 tons. Peak war production in 1942 was 27 percent below the all-time peak established in 1925.

The quantity of zinc available at 6 cents in the reserves estimated ³ as of 1944 was 11,200,000 tons of recoverable metal, more than half of which was in inferred ore. Under emergency prices the total reserve was believed to contain nearly 17,000,000 tons.

Production of lead and zinc may be expected to decline within a few years. Zinc has been particularly affected by depletion in the Tri-State district, which produced over 400,000 tons or 55 percent of the total output of the country in 1926, and contributed only 200,000 tons or 27 percent of the total in 1943. A substantial part of the district's output during the war has required premium prices, and an abrupt drop is anticipated with a return to peacetime conditions after the war. Without exception, all the important lead-producing districts that contributed to the record output of 1925 produced considerably less lead in 1942.

² Cannon, Ralph S., U. S. Geological Survey, and Mosier, McHenry, U. S. Bureau of Mines.

³ Estimates for lead and zinc by E. T. McKnight of the U. S. Geological Survey and E. F. Fitzhugh, Jr., of the U. S. Bureau of Mines.

POSTWAR SELF-SUFFICIENCY

The discussion up to this point indicates that unless new reserves are developed we are facing some changes in our "have" and "have-not" status in minerals. These are only relative terms, however, and consequently do not necessarily connote affluence or poverty. The United States has been the most self-sufficient nation of the world in minerals yet it has always had important deficiencies. Figure 10 shows the status in 33 principal industrial minerals in the 5-year period 1935 to 1939. Manganese, chromite, and nickel are indispensable in our in-

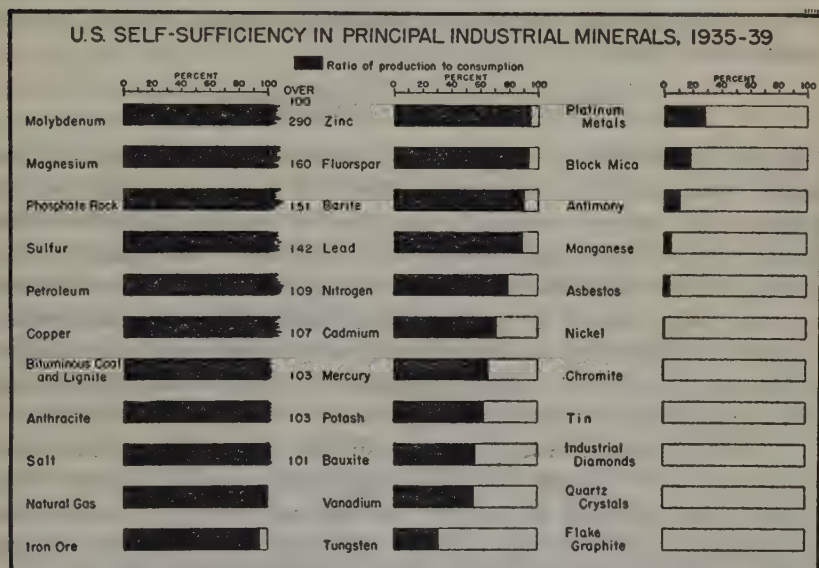


FIGURE 10.—Production of principal industrial minerals in the United States expressed in percentage of domestic consumption, 1935-39. Building materials (stone, cement, lime, etc.) for which the United States is self-sufficient, are not included.

dustrial structure, yet we have imported almost all our needs for decades. These deficiencies and others that may develop need cause little anxiety as to national security provided proper steps are taken to buttress our defense against shortages in time of war.

We have been able to export part of our production of the first nine minerals listed in the column at the left. The tenth mineral, natural gas, is not exported to any extent. We are a net importer of most of the metals. On the basis of available reserves and probable postwar domestic requirements we can continue to export for some time all but two of the minerals we shipped abroad before the war. An import status for copper and petroleum is anticipated within a decade. Domestic reserves or installed capacity could support for various periods

an improved "have" status for iron ore, barite, nitrogen, potash, and possibly fluorspar if such status were desirable. On the other hand, greater dependence on foreign sources of zinc, lead, cadmium, mercury, bauxite, vanadium, tungsten, platinum, and block mica is indicated. Little change can be anticipated in the remaining commodities which are chiefly imported. Submarginal resources of our deficient minerals that give us a potential "have" status under emergency conditions and at high prices are those of bauxite, manganese, vanadium, flake graphite, chromite, nickel, and mercury. As previously noted, our submarginal resources of manganese, vanadium, and off-grade bauxite, and other aluminous minerals are relatively large in terms of prewar consumption rates.

MINERAL POLICY CONSIDERATIONS

From the foregoing analysis, and assuming our appraisal of domestic resources to be reasonably correct, it is apparent that our dependence on foreign sources for supplies of certain minerals will be greater in the future than it was before the war. The question thus arises as to the significance of these changes and what alterations in national policy should be made to meet them. Time does not permit discussion of all policy aspects of the mineral-supply problem so I shall confine my remarks to a brief discussion of those involving national defense, assurance of peacetime supplies, . . . and conservation.

National defense.—A major responsibility of the Nation is to maintain its ability to defend itself from aggressors, and to this should be added, in anticipation of postwar international political cooperation, the assurance of its ability to carry out such responsibilities as may be assigned to it. As our self-sufficiency declines, our military power is adversely affected, and the problem of strategic minerals becomes more acute. Thus, the need for large-scale stock piling is of utmost importance; because stock piling is a device for supplementing our domestic resources, the stock piles should be made up largely from foreign materials, for that is the only way we can add to our basic mineral resources. It is the surest way of guaranteeing our basic security in minerals in time of need. It has been suggested that, in view of the impending "have-not" position in certain minerals, we should shut down our mines and preserve the resources remaining in the ground for future emergencies. From a theoretical viewpoint this argument has appeal, but from a practical standpoint the cost is too great. It imposes too severe a burden on the present generation by asking it to swap a bird in the hand for only one crippled bird in the bush to be saved for the use of future generations. The program would result in resource waste because much of the unmined portions of deposits now developed probably never could be recovered after

a prolonged shut-down. Also, the abrupt curtailment of mining would present a serious social problem in readjustment of the population that would be stranded in isolated mining areas. Huge capital losses would be incurred. For these reasons, the proposal does not seem to merit serious consideration.

Our national security cannot rest entirely on stock piles. Experience since 1939 clearly demonstrates the fallibility of even the experts. They cannot foresee with certainty the magnitude or duration of an emergency. For this reason we need a second line of defense to provide against mistakes in stock-pile planning. Our marginal and submarginal resources can give us that additional insurance. Exploration for new deposits should be carried on vigorously and methods for processing these materials should be perfected and plans made for emergency production. It is not unreasonable to expect that such a program might lead to the development of new peacetime industries. Our large deposits of manganese-, vanadium-, and aluminum-bearing materials offer interesting possibilities.

The program just outlined is essentially the same as that recommended to Congress by the Army and Navy Munitions Board in its recent report on strategic materials.

While the accumulation of stock piles from foreign sources should be a basic requirement for national defense, a large-scale stock-piling program could also provide a reservoir into which domestic materials might be placed in times of depression with resultant economy to the Nation and benefits to the mining communities. Consider the advantages that would have accrued had we kept a reasonable measure of employment in the mining areas during the depths of the depression, and stock-piled the surplus production for future use. Not only would the effects of the depression in the mineral-producing areas have been less severe, but we would have had a substantial inventory that would have eased greatly the procurement problem of the last few years.

Peacetime supplies.—Stock piling will provide for the defense of the Nation but will not assure adequate supplies of minerals at reasonable prices during peacetime. There are several ways in which the Government can be helpful in attaining the latter objective. A fundamental requirement in dealing with this problem is more detailed knowledge of the extent of our reserves. Our studies have revealed many inadequacies in basic information necessary for the quantitative appraisal of resources. The United States Department of the Interior plans to remedy this situation. The mining industry can be very helpful by making available to the Government the vast amount of information of this type in company files. We realize that such data frequently must be regarded as highly confidential and the reluctance of some producers in the past to make them available is readily under-

stood. This reluctance is gradually disappearing, and it is hoped that in the postwar years the mining industry will continue to be as generous in supplying data as it has been during the war. By so doing, the best interests of all are served. Policy decisions are made in Washington that affect your industries. These policies are usually formulated on the basis of available facts. If the full facts are not available, errors of judgment can be made. Obviously the wisest decisions on policy are possible only if all the facts are known.

An objective appraisal of recent experience suggests that prospecting and exploration are reaching marginal limits so that the expenditure of private funds in the search for new mineral deposits is becoming more difficult to justify. This suggests that the Government should assume some of the risk involved in keeping our mineral development going. The Geological Survey and the Bureau of Mines are planning extensive postwar projects to assist in accomplishing this objective through a systematic geological and exploration program designed to develop information that will help mineral producers plan exploration programs and provide a reliable inventory of our mineral resources. This program will in no way interfere with the activities of private enterprise but, to the contrary, will provide it with basic data that will permit the mining industry to carry on its search of new mines more effectively.

The Government's exploration program should be supplemented by extensive research and testing to develop new and cheaper methods of bringing our larger marginal resources into commercial production and to provide substitute materials for those that play out. I want to make it clear that I am not referring to hothouse industries that can exist only at the expense of the public treasury or the consumer. New peacetime industries can survive only if they are based on sound technology and economics.

The Government also has a responsibility to encourage the importation of those minerals essential to our industry, and which cannot economically be produced at home in sufficient quantities. Through fact-finding and diplomatic services the Government can assist American capital to engage in foreign mineral development. It should support American enterprise abroad to see that it is permitted to operate with reasonable security and under conditions that are fair to all parties concerned. Such a policy is fully compatible with a respected membership in the family of nations because it results in the development of resources and employment abroad while supplying us with useful raw materials; it also permits constructive use of our surplus capital.

[EDITOR'S NOTE.—Author's discussion of tariff policy has been deleted in this reprint.]

Conservation.—A review of our mineral position requires some general comment on conservation. History shows that as a nation we talk a great deal about conservation but are unwilling to put up much cash for it. In the lush days of our industrial growth, we were little concerned about the extravagant use of resources to achieve low-cost production. Now that we are beginning to feel the effects of exhaustion perhaps a more far-sighted view may prevail. Some waste of resources occurs through lack of techniques with which to do the job of producing and using minerals better. Much progress has been made along this line through research and the efforts of our profession. Research and engineering and the scrap-metal industry should be recognized as the greatest conservational forces at work today, and the Nation owes a debt of gratitude for their accomplishments. Further progress in these lines may be expected. On the other hand increasing labor costs and taxation are decidedly anticonservational. Pains-taking efforts to reduce costs to permit mining of marginal ores by technical improvements can be wiped out by wage and tax increases. Yet the latter are inevitable consequences of our social progress. I see no easy answer to this conflict of objectives.

Cooperation between Government and industry can do much to smooth out the economic factors that are the cause of most of the harmful waste in the utilization of mineral resources today. Elimination of the extremes of competition, the stabilization of prices and production, and some controls to prevent frivolous uses of scarce minerals that are of strategic importance to the Nation will promote conservation and at the same time improve the economic condition of the industry. We gained some experience along this line in coal and petroleum before the war and a lot more during the war. If we can maintain this teamwork in the postwar years conservation can be achieved on a worth-while scale. In view of the rapid rates at which we are exhausting our mineral deposits, such conservation is very much in order, but its ultimate effect on our basic mineral position will not be highly significant. Our best hope for substantial improvement in those minerals where exhaustion is near lies in research on our submarginal resources and in taking the risk of prospecting for concealed deposits that now lie hidden in the earth's crust. These measures should be carried on vigorously, but while we hope for successful accomplishment we should also take measures to facilitate the procurement of more of our mineral requirements from foreign sources.

JAPANESE EARTHQUAKES¹

By N. H. HECK

[With 3 plates]

INTRODUCTION

In these days of global warfare, and in anticipation of a world-wide view in the future, there is need of more geographical and geophysical knowledge. So outstanding a feature as earthquakes in Japan cannot be disregarded. Much has been written on the subject by Japanese seismologists and others, and by two Englishmen—John Milne (1850–1913)² and, more recently, Charles Davison.³ Milne, who went to Japan in 1876 to aid in the establishment of that country's new educational system, became interested in earthquakes and began investigations, which were taken up by Omori and others. Many of his writings were based on direct observation; otherwise, nearly all information, including Davison's, is from Japanese sources. Since from Milne's time onward Japan has been treated as an earthquake laboratory, much material has been published, part of it in foreign languages, and especially in English.⁴ However, nowhere is there a brief comprehensive discussion of the principal Japanese earthquakes.

There is a general impression that Japan is more subject to major earthquakes than any other area of similar extent. Imamura⁵ states that there have been 300 great earthquakes during the period of recorded history. Of these he lists 59 from 1596 to 1935 inclusive, for which statistics and at least partial descriptions are available. Some of the entries may be debatable and some of the statistics may be doubtful, but since they represent all kinds of earthquakes and associated occurrences they are made the basis for the present discussion and are listed in table 1.

¹ Reprinted by permission from the Bulletin of the Seismological Society of America, vol. 34, No. 3, July 1944.

² See Mrs. Lou Henry Hoover, John Milne, seismologist, Bull. Seism. Soc. Amer., vol. 2, pp. 2–7, 1912.

³ The founders of seismology, Cambridge, England, 1927; The Japanese earthquake of 1923, London, 1931; Great earthquakes, London, 1936.

⁴ In preparing the present paper, I have drawn upon various bulletins of the Imperial Earthquake Investigation Committee, Tokyo, and of the Earthquake Research Institute of Tokyo Imperial University; also The great earthquake of 1923 in Japan (in English), compiled by the Bureau of Social Affairs, Home Office [Tokyo], 1926.

⁵ Imamura, Theoretical and applied seismology, Tokyo, 1937.

TABLE 1.—*Destructive Japanese earthquakes, 1596–1943*

No.	Yr.	Mo.	Day	Lat. N.	Long. E.	Houses destroyed	Deaths	Locality and remarks
1	1596	IX	4	33	132	-----	700	Oita. T. Urya-zima subsided.
2	1596	IX	5	35	136	-----	2,000	Husimi.
3	1605	II	3	32.5	138	-----	5,000	Tokaido, Nankaido, Saikaido. Great T.
4	1611	IX	27	37.5	140	-----	3,700	Aidu. Inawasira subsided.
5	1611	XII	2	40	144	-----	3,000	Hokkaido and Sanriku. Great T.
6	1614	XI	26	37.5	138	-----	Many	Takata in Etigo.
7	1633	III	1	35.5	139.5	-----	150	Odawara.
8	1649	VII	29	35.5	140	-----	Est. 200	Tokyo.
9	1659	IV	21	37.5	140	406	39	Vicinity of Aidu and Nasu.
10	1662	VI	16	35.5	136	5,500	600	YAMASIRO and OOMI.
11	1662	X	30	31.5	132	3,800	20	HYUGA and OOSUMI.
12	1666	II	1	37	138	-----	1,500	Takata.
13	1676	VII	12	34.5	132	133	7	Tuwano.
14	1694	VI	19	40	139.5	2,760	394	S. Nosiro in UGO.
15	1703	XII	31	34.5	140	20,162	5,233	Boso Pen., SAGAMI and MUSASI. Great T.
16	1704	V	27	41	139.5	1,314	58	North of Nosiro.
17	1707	X	28	32.5	136	29,000	4,900	Same places as No. 3. Great T.
18	1711	III	19	35.5	133	500	4	MIMASAKA, INABA, HOKI.
19	1714	IV	28	36.5	138	300	56	Oomati in SINANO.
20	1729	VIII	1	37.5	137	791	5	NOTO, SADO.
21	1751	V	20	37.5	138	9,100	2,000	Takata.
22	1766	III	8	41	141	7,192	1,335	Hirosaki.
23	1792	V	21	32.5	130	12,000	15,200	HIZEN, HIGO. Eruption Unzen-dake. T See p. 216.
24	1793	II	8	41	140	164	12	W. Tugaru, Adigasawa. Small T.
25	1802	XII	9	38	138	1,150	20	SADO.
26	1804	VII	10	39	140	5,500	333	Kisakata.
27	1810	IX	25	40	140	1,129	59	Oga Peninsula.
28	1828	XII	18	37.5	139.5	11,750	1,443	Sandyo in ETIGO.
29	1830	VIII	19	35	136	-----	280	Kyoto.
30	1833	XII	7	38.5	139	1,013	42	UZEN, SADO. T.
31	1847	V	8	37	138	34,000	12,000	SINANO, ETIGO.
32	1853	III	11	35.5	139.5	3,300	79	Odawara.
33	1854	VII	9	35	136	5,000	1,352	Iga, Ise, YAMATO.
34	1854	XII	23	33.5	138	60,000	3,000	Tokaido, Nankaido. Great T.
35	1854	XII	24	32.5	134	(1)	(1)	Great T.
36	1855	XI	11	36	140	50,000	6,757	Tokyo.
37	1858	IV	9	36	137.5	709	203	Northern part of HIDA.
38	1872	III	14	35	132.5	5,000	600	Hamada in IWAMI.
39	1889	VII	28	31.5	131	239	20	Kumamoto.
40	1891	X	28	35.5	137	142,177	7,273	MINO, OWARI.
41	1894	III	22	42	145.5	11	-----	Nemuro, Hokkaido. T.
42	1894	VI	20	36	140	90	24	Tokyo.
43	1894	X	22	38	139	6,006	726	Syonai.
44	1896	VI	15	39	143.5	106,170	27,122	Sanriku. Great T.
45	1896	VIII	31	40	141	5,911	206	Senhoku, UGO.
46	1905	VI	2	34	133	59	11	AKI.
47	1909	VIII	14	35.5	137	976	41	Near Ane-gawa, OOMI.
48	1911	VI	15	28	131	422	12	Kikai Island.
49	1914	I	12	31.5	131	120	29	Sakurijima, eruption; casualties omitted.
50	1914	III	15	39.5	140	640	94	Senhoku, UGO.
51	1922	XII	8	33	130	376	27	Simabara, HIZEN.
52	1923	IX	1	35	139.5	576,262	99,331	Kwanto. T.
53	1924	I	15	35.5	139.5	1,273	14	Central SAGAMI.
54	1925	V	23	36	135	3,333	395	E. TAZIMA.
55	1927	III	7	36	135.5	16,025	3,017	TANGO.
56	1930	XI	26	35	139	8,099	259	Northern IDU.
57	1931	IX	21	36	139	115	13	Northwestern MUSASI.
58	1933	III	3	38.5	143	4,086	2,986	Sanriku, Great T.
59	1935	VII	11	35	138	115	13	Siduoka.
60	1936	XII	27	34.4	139.2	300	3	Nii Jima.
61	1939	V	1	40	140	295	29	Near Akita.
62	1943	IX	15	35.5	134	(2)	(2)	Tottori.
63	1944	XII	7	33	137	-----	-----	Off Kii.

¹ Effects not separated from No. 34.² Unknown.

(Explanation: Latitude and longitude are only for the purpose of finding epicenter in fig. 4. Number of houses destroyed and deaths include those by earthquake and those by fire and tsunami due to earthquake. Names of provinces into which Japan was long divided are in capitals and small capitals, and their locality is obtained from fig. 1. Names ending in -aido refer to ancient circuits or groups of provinces, the names indicating direction from Kyoto, the ancient capital. T=tsunami.)

Four earthquakes are added to bring the list up to date. This limited selection might lead to the conclusion that there are no earthquakes in other areas, but such is not the case. If we accept the figures

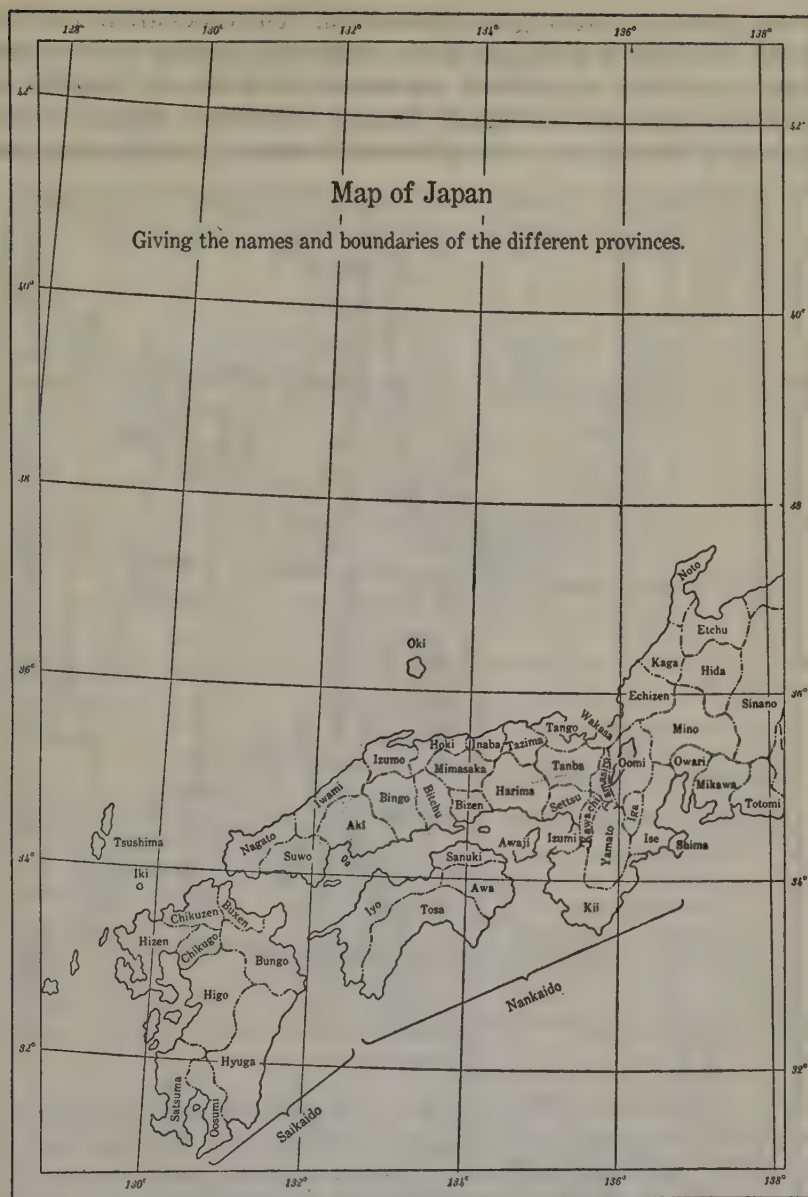


FIGURE 1.—Map of Japan giving names and boundaries of the different provinces.
Southern part.

in table 1, the deaths have exceeded 200,000 and the number of buildings destroyed directly by earthquake or indirectly by fire or tsunami (a convenient Japanese word for tidal wave, or seismic sea wave due to earthquake) totals about 1,200,000. These figures, whether accurate

or not, give a picture of great destruction. The losses are in part due to the density of population: Japan is the only country in which two large cities with a combined population in excess of 6,000,000 are subject to the same earthquake hazard. However, Japan's seismic activity is likely to be overemphasized because (1) of the many per-

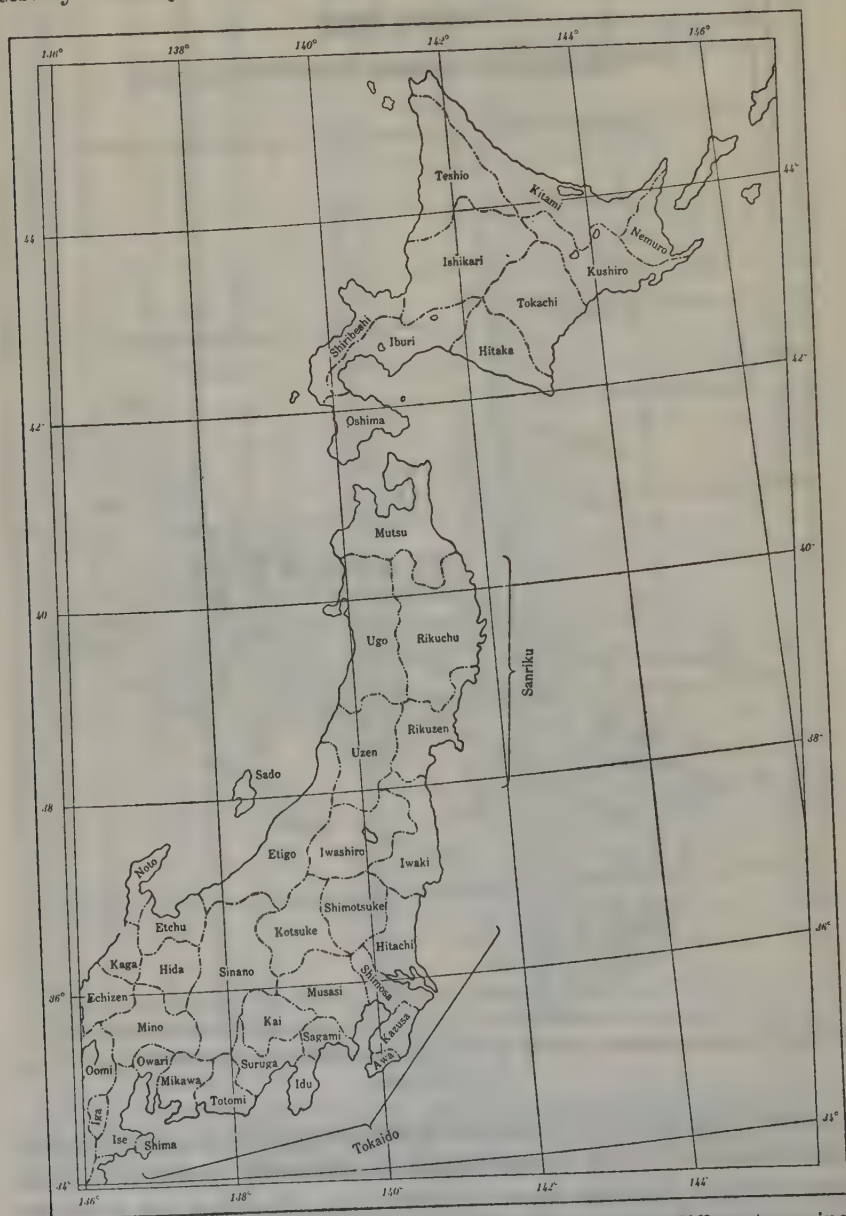


FIGURE 2.—Map of Japan giving names and boundaries of the different provinces. Northern part.

sons to make reports, (2) of a statistically minded government, and (3), in recent years, of an extensive network of seismographs. Gutenberg,⁶ after careful investigation, has reached the conclusion that the main Japanese islands and adjacent seismically active sea bottom are probably no more seismic than some other areas of equal extent, but

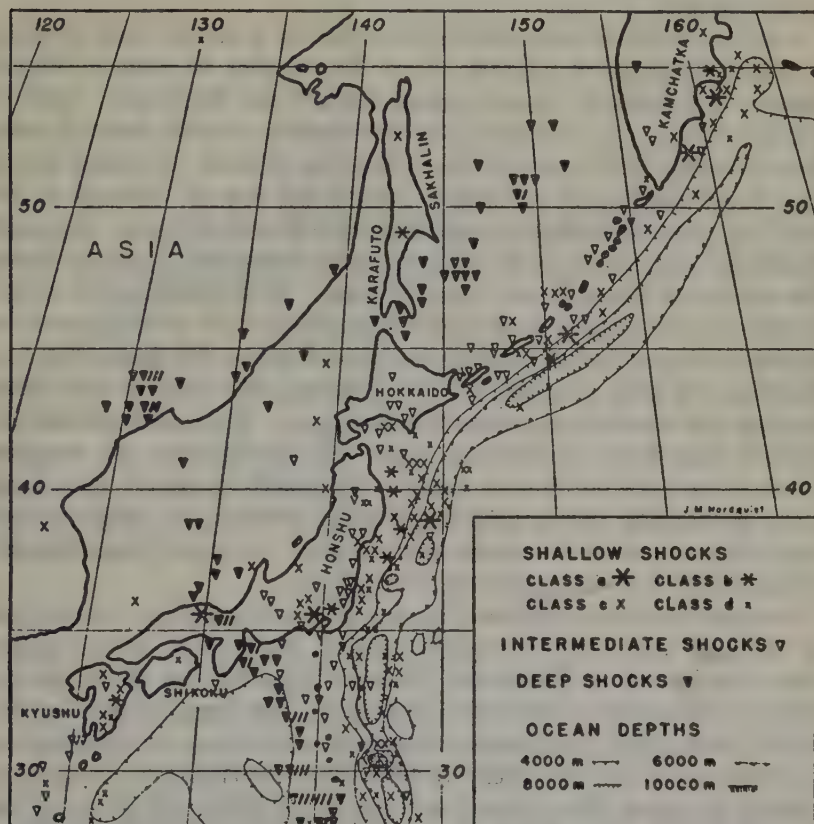


FIGURE 3.—Map of epicenters, Japan to Kamchatka. (Courtesy Geological Society of America.)

he considers that the seismicity of certain local areas in Japan reaches a peak rarely, if ever, exceeded elsewhere. In Japan there have been examples of every kind of earthquake except one—that occurring at times in eastern North America, felt over a vast area but usually at only moderate maximum intensity.

GEOGRAPHICAL DISTRIBUTION

Distribution according to depth.—This is so complex that the following statement, based on Gutenberg (see footnote 6) and figure 3,

⁶ B. Gutenberg and C. F. Richter, *Seismicity of the earth*, Geol. Soc. Amer., Spec. Pap., No. 34, 1941.

though essentially correct, is an oversimplification. The classification of Gutenberg will be followed: shallow earthquakes have a depth of less than 36 miles; intermediate, between 36 and 180 miles; and deep, more than 180—the greatest known, 420 miles. The more destructive Japanese earthquakes are shallow or in the upper portion of intermediate depth.

A belt of shallow earthquakes paralleled by a narrow belt of intermediate earthquakes extends from Kamchatka to central Japan, whence it follows the island groups toward the Marianas. Another belt of shallow and intermediate earthquakes extends from Kyushu Island toward Formosa and the Philippine Islands. A broad belt of deep-focus earthquake epicenters crosses the Sea of Okhotsk to the southern part of Sakhalin, paralleling the Kurile Islands. Opposite Hokkaido and northern Honshu, the deep-focus belt is in the Japan Sea or inside the adjacent Asiatic coast. This almost joins a belt nearly at right angles to it which, beginning with a large group of shocks on the continent, follows southward across the Japan Sea and Honshu and then parallels to the westward the shallow and intermediate belt extending toward the Marianas. The southwestern belt has no deep-focus earthquakes until the Philippines are reached. There is no need of further detail. It should be stated that deep-focus earthquake waves must have great intensity to cause serious destruction, because the waves have already traversed a considerable distance before reaching the earth's surface.

Geographical distribution of destructive earthquakes.—On account of the high seismicity, discussion will be confined to Japan proper (the four islands of Hokkaido, Honshu, Shikoku, and Kyushu) and adjacent submarine areas, and to Formosa. The Japanese earthquakes which have made the greatest impression are those originating on the western side of the Tuscarora Deep from off Hokkaido to opposite Tokyo, the great Mino-Owari earthquake of 1891, and those of the Kwanto region (named for an extensive plain which includes Tokyo and Yokohama). However, other parts of Japan have suffered earthquake catastrophes. For the sake of convenience, a number of principal areas will be listed and then characteristic earthquakes of each will be discussed, particularly those which have some striking feature.

DESTRUCTIVE EARTHQUAKES BY REGIONS

Region I. Submarine area west of Tuscarora Deep. Shocks causing little direct damage produce great tsunamis.

Region II. Submarine region off southwestern Japan, Idu to Kyushu and adjacent islands. Great damage both from earthquakes and tsunamis.

Region III. Kwanto region, named for great plain. Shocks highly destructive in region of great cities. Tsunamis secondary.

Region IV. Central Japan. Mino-Owari, Kyoto, and Tazima-Tango areas. Visible fault slips in severe earthquakes. No tsunamis.

Region V. Japan Sea coast of Honshu, except Tazima-Tango. Earthquakes generally less severe than in regions I-IV. Tsunamis small.

Region VI. Interior of Honshu, not included in regions III and IV. Characterized by landslides.

Region VII. Kyushu Island. Shocks usually associated with volcanic activity.

Region I. Submarine, west of Tuscarora Deep.—Only 4 of the 63 great earthquakes are in this region; but this is not a complete picture. Omori states that from the year 416 to about 1900 there were 23 great tsunamis in regions I and II, and he found that of 257 shocks felt over an area of more than 25,000 square miles, recorded from 1885 to 1905, 145 were in the same region. Imamura lists 15, some moderate, in region I, from the year 869 to 1933. This supports his statement that region I is the breeding ground of big earthquakes and that the adjacent Sanriku coast is never free from the danger of destructive tsunamis. Those of 1896 and 1933 will be described. The former was the greater one, but the 1933 tsunami received the most thorough scientific investigation ever given to this phenomenon.

The 1896 earthquake was felt from Hokkaido to the Kwanto region, but no important damage was caused. The shock was slow and undulating. About 20 minutes later, a wall of water 10 to 20 feet high at most places rushed in, and, as people were celebrating a holiday on the beaches, thousands were swept away and drowned and many villages were laid flat. The waves reached a height of nearly 100 feet at one place and 75 feet at a number of others. However, the damage was nearly as great for a wave of 20 feet as for greater heights. Fishermen who were well offshore failed to recognize anything unusual and were greatly surprised on their return homeward to find the sea strewn with house wreckage and corpses. The wave was recorded by the tide gage at Sausalito, Calif.

The great variety of height of wave was studied for the 1933 earthquake. The circumstances for the arrival of the wave were the same as those in 1896, though it had less amplitude. The height over the deep Pacific Ocean was estimated at 3 feet, and the wave length at 60 to 600 miles, which has much to do with recording at a distance. The wave was recorded by tide gages in California and the oscillations were noticed at Iquique, Peru, 9,000 miles from the place of origin. On the coasts of Honshu and Hokkaido the usual height was 7 to 15 feet, but there were maximum heights of 96 feet and 75 feet at several places. In one bay the height was 10 feet at the entrance, 26 feet halfway up the bay, and 75 feet at its head. Off one of these bays a motorboat capable of a speed of 12 miles an hour could not make headway. The explanation of the increase of height lies in the V-shaped character of the bay. The wave in some places arrived as a flood, resembling a very high tide, and at others it arrived as a vertical wall like a great breaker—with high horizontal acceleration. Usually a withdrawal

of the sea preceded the arrival. It appears that usually there was only one great wave; but not always, and the later wave might be greater than the first. The Japanese have classified their exposed harbors on the basis of the type of tsunami to be expected. (Pl. 1, fig. 1.)

Region II. Submarine, offshore, Idu to beyond Kyushu.—Of the earthquakes of table 1, eight were in this region, but the remarks introducing region I should be noted. The earthquake of 1703 possibly belongs to region II, but it is properly assigned to region III because of its relation to the Kwanto earthquake of 1923. Prior to 1596 there were great submarine earthquakes in region II; one in 684 which caused notable damage in the vicinity of Koti on southern Shikoku, where low ground containing two villages sank beneath the sea, and one in 1361, accompanied by a tsunami which caused damage at Osaka. Of the earlier shocks of table 1, that of 1605 caused heavy loss of life. Special attention is given to three earthquakes, one in 1707 and two in 1854. The latter were only a day apart but in very different locations. However, in some places the effects were separated with difficulty. There were strong shocks in 1936 and 1944.

The 1707 earthquake was among the greatest known in Japan. Houses were damaged or destroyed in 26 provinces and the tsunami swept the coast from Kwanto to Kyushu Island. Near Koti in southern Shikoku the wave was 91 feet high. The waves not only swept the outer coast, but entered the Inland Sea (between Shikoku and Honshu), leaving wreckage. A great wave rushed into Osaka Bay, causing great havoc. Two rivers enter the bay at Osaka after traversing the central part of the city, and there are therefore many bridges. More than 1,000 craft of various sizes were swamped and sunk, but many were carried by the wave, damaging bridges as they swept along.

Of the two earthquakes of 1854, the first was off Totomi Sea and the second off Shikoku. The tsunami from the first shock consisted of three waves in the harbor of Shimoda on the southern end of Idu Peninsula, causing the foundering of the Russian frigate *Diana* and of many Japanese vessels, which gave the harbor a bad repute.

The situation at Osaka was of special interest. The first shock, about 8 a. m. December 23, was felt strongly, but the tsunami was only moderate. Many persons decided to spend the night outside their houses, and some took refuge on boats and vessels. Two hours after the second shock, which occurred about 5 p. m. on the 24th, a tsunami arrived which was 10 feet high in the outer harbor and 20 feet in the port. More than 1,500 vessels were damaged or completely wrecked and, as in 1707, some were swept along by the wave, damaging 25 bridges. As there is no high land to which one may flee in Osaka, and as similar waves sometimes accompany typhoons, the

building of a great breakwater has been considered, but an effective one is scarcely practicable. The earthquakes of 1911 and 1936 may have produced large tsunamis, but, since they occurred off small islands, the damage occasioned was not great. The submarine shock of 1944 was stronger than the destructive 1923 earthquake.

Region III. The Kwantō region.—This region, named for a great plain which covers most of the region, includes the Idu Peninsula west of Sagami Bay. For the years from 818 to 1930, Imamura lists 28 destructive earthquakes, including 9 of those listed in table 1. The persistence of destructive earthquakes in the region for more than 1,900 years is evidenced by a series of horizontal lines of drill holes in a cliff on a recent inlet of Sagami Bay near Misaki. The holes were made by a marine borer which operates only between high and low water. The lowest row indicates an uplift of 17 feet in 1703; the next, of about the same amount in 818; and a less definite one which, on fairly good evidence, is assigned to about A. D. 33. In 1923 the uplift was about 6 feet. In the earthquake of this year, and probably in the others, there was lowering elsewhere, indicating block tilting. This is probably the clearest example of successive uplift to be found anywhere.

The 1703 earthquake was submarine, with its origin south of Boso Peninsula (east of Tokyo Bay). There was a tsunami of some violence over a moderate length of coast, possibly due to sea-bottom changes which at that time could not be measured. The earthquake was destructive in nine provinces. There was uplift at many places along the coast, and some previously outlying reefs became dry land. The loss of life and property damage was heavy, but not so great as it would have been under the conditions of industrialization of 1923.

The earthquake of 1855 was noteworthy in that, though it was local in extent, its epicenter was nearer to Tokyo than that of 1923 and therefore it caused important damage. Many fires were started when charcoal braziers were upset by the earthquakes, but most of them were brought under control though a square mile of the city's area was burned. The shock was of very short duration.

Books have been written about the earthquake of 1923, generally known as the Kwantō earthquake (pl. 1, fig. 2; pl. 2). An elaborate report of the engineering features, published in Japanese, was translated into English by the American Society of Civil Engineers; but the translation has not been published, though it is available at the Society's library in New York. Only a bare outline of the principal facts of the earthquake can be given. The epicenter of the first main shock was in the middle of Sagami Bay, where the changes that took place were great, though perhaps not so great as the comparative hydrographic surveys taken before and after the event seem to indicate.

There were numerous severe aftershocks, and one on the following day about 40 miles to the eastward was nearly as great as the main shock. Soon after the main shock a tsunami swept Sagami Bay and the adjacent coasts. Its maximum height was 36 feet, though 10 to 16 feet was more common. These heights scarcely correspond to the reported great displacement in the epicentral region. In some places uplift of the land reduced the effect of the tsunami.

The shock occurred just as the noon meal was being prepared, and people rushed from their houses, abandoning overturned stoves. The fallen wooden houses, and drugs, chemicals, and gasoline, amply fed the flames. A total of 134 separate blazes were counted, and these soon joined in a single conflagration. A fully efficient fire department could have done little, as the earthquake had put the water system out of order. There was a shifting wind, reaching a velocity of nearly 50 miles per hour, and the conditions set up tornadoes. It is said that 40,000 persons died in one group in an open city square. That no one escaped has been attributed to fires in possessions of the refugees, but there is reason to believe that many deaths were due to lack of oxygen in the air. A similar cause of death has been suggested in the burning of Hamburg, Germany. In Tokyo, an area of 7 square miles was burned and only 15 percent of the buildings escaped. Many of those lost were government and business buildings, libraries, art galleries, and museums, so that the loss of irreplaceable books, records, and objects of all kinds could scarcely be evaluated.

Yokohama was only 40 miles from the epicenter, as against 57 for Tokyo, and the damage from earthquake was 10 times as great. Three square miles, or half the total area of the city, was burned. The loss from fire was 60 percent of the buildings, but the earthquake damage accounted for 20 percent more, leaving only 20 percent undamaged. In a town near the epicenter 95 percent of the houses were thrown down.

Damage to structures and public utilities will be briefly described. It was estimated that 18,000 factories were destroyed. Large buildings in Tokyo stood the shock fairly well. About half the tall stacks fell. Bridges suffered severely; wooden bridges were burned, and some steel spans were thrown off the piers, or were distorted when slides or mud flows moved the abutments, shortening the distance between them. Many of the bridges carried pipes and electric lines, and so the effective damage was increased. Fallen bridges prevented the escape of refugees. A total of 2,270 vessels, mostly of small size were lost.

More than 400 miles of railway were damaged by vertical or horizontal ground displacement, with damage to tunnels and culverts. Streetcars and generating systems were damaged by fire and landslides. In Tokyo, 56 miles of canals were damaged by slides. In Yokohama, 4,800 feet of breakwater settled 8 feet or more and the 1,300-foot land-

ing pier suffered severely. Off Yokosuka, part of the breakwater sank 18 feet. Eleven lighthouses were destroyed.

Damage to the water systems included effects of landslides and shifting of underground conduits. This was the more serious since the use of water carts increased the danger of epidemics of water-borne diseases; but fortunately that danger was fairly well avoided. Replacing of house services was a major task since pipes were broken and pulled apart. The tanks of the gas works were generally uninjured, but the distribution systems were badly wrecked. A number of explosions occurred in large pipes where gas was trapped. It required 7 months to make replacement complete. Sewers were chiefly affected by breaks at watercourses or where sewers met. Many manholes were damaged.

It will be seen that damage was caused by earthquake waves, by slipping or cracking or sliding of the ground, by fire, and by tsunami. Evidently, a major earthquake is an effective agent of destruction.

A phenomenon of unusual interest occurred in a town in the Boso Peninsula. In an old rice field filled with water, the teachers in a nearby school saw two fissures 130 feet long spurting muddy water to a height of 10 feet, repeating like a geyser six times before ceasing. The only comparable actual observation of the same phenomenon was in the Bihar, India, earthquake of 1934. Only rarely has the effect of earthquake on ground water been actually observed.

There were great landslides on several peninsulas (pl. 1, fig. 2). A village of 700 people was buried under an immense avalanche of soil and rock. During the last week in September there were 1,256 after-shocks of all degrees of intensity.

In the northern Idu earthquake of 1930 near Ito and Awami, on the west shore of Sagami Bay, 7,000 buildings were damaged and several hundred lives were lost; but this is relatively minor for the region. There were 2 notable features, swarm earthquakes and luminous phenomena. The main earthquake occurred on November 26. A seismograph at Misaki, 31 miles away across the bay, recorded 3,684 after-shocks of a wide variety of intensity from February 13 to April 11. The greatest number, 209, and the strongest shock, which was somewhat destructive, occurred on March 9. After a pause, the shocks started again on May 7, and attained their greatest frequency about the middle of the month. Few occurred after May, and all stopped in August. The number recorded in the two series reached 6,000, of which about 4,900 were felt at Ito. During March, additional seismographs were installed and positions and depths of epicenter were studied. Early in November, the shocks started again. Great numbers occurred, the greatest in a single day being 690 on November 25.

On November 26, 236 were recorded in a single hour, but on the day of the great earthquake there were very few.

The Tanna tunnel (nearly 5 miles long) on the railway from Tokyo to Kobe was under construction and the fault on which slipping occurred had already been crossed. The west side of the tunnel where it crossed the fault was shifted about 8 feet southward and 2 feet downward. Otherwise no damage was done, though in a village directly over the tunnel 55 percent of the houses were thrown down. Seismograms showed that for periods of 1 second or less the amplitudes above were two to four times that in the tunnel, while for periods of 4 or 5 seconds there was no difference in amplitude.

Triangulation before and after the earthquakes showed that the movements were in opposite direction on both sides of the fault by similar but not equal amounts. From 1896 onward, many lines of precise levels were run in the region. In the vicinity of Ito there were two levelings before and two after the principal earthquake. It was found difficult to find the relation between the vertical changes and earthquake occurrence.

The reports of luminous phenomena in connection with this earthquake, totaling 1,500 over an area of about 7,300 square miles, seem to confirm similar reports in regard to certain Sanriku earthquakes. They started a short time before the main earthquake (about 4 a. m.) and continued for an hour in the epicentral region. Some lights were like rays of the sun, some like searchlights, and others like fire balls. They were colored from red and yellow to blue. Some of them were brilliant. Although, in Japan, they have usually been attributed to luminous microscopic organisms in the sea disturbed by earthquake or tsunami, the explanation is not wholly satisfactory.

Region IV. Mino-Owari, Kyoto, Tazima-Tango.—Imamura lists 14 shocks in the Mino-Owari region from 745 to 1918, and 18 in the Kyoto region from 701 to 1830 (none thereafter), and none before 1926 in the Tazima-Tango region. Of those listed in table 1 there were 8 in the entire region. The only shocks requiring detailed discussion are the Mino-Owari of 1891, the Tazima of 1925, and the Tango of 1927. The Mino-Owari was the greatest, though similar shocks in 745, 1185, and 1586 were probably severe.

The 1891 earthquake occurred south of the center of a long fault or series of faults which extended in a northwest-southeast direction across Honshu near its narrowest width. The visible fault slips extended for 40 and probably for 70 miles. They were generally en échelon, with a maximum vertical slip of 20 feet and a maximum horizontal slip of 13 feet.

This was one of the greatest of Japanese earthquakes. It was too early for cities of the region, such as Nagoya, to have become indus-

trialized, but various types of structures having a design, borrowed from other countries, which ignored earthquakes, were destroyed. The region is primarily agricultural, one of the most important rice-raising districts of Japan, and in spite of its few cities the population density was second only to the Tokyo-Yokohama region, being 778 per square mile. The intensity is evidenced by the loss of 140,000 houses, only a few of which were destroyed by fire. Along some of the highways every house was down. (Pl. 3, fig. 1.)

The area of greatest destruction covered 4,300 square miles. The rice culture required many roadways and ditches and there was heavy damage to them and to embankments. A number of bridges suffered, some spans being thrown off the piers. An area of three-fourths of a square mile subsided so that a river mouth was blocked and the land became swampy. In one place the faulting resulted in complete destruction of a village, a half acre of land being turned over so that nothing remained but clods and upturned roots. At another place two persimmon trees in a garden were shifted, without damage, so that the direction between them changed from east-west to north-south. Buildings were damaged as far away as Osaka. There were great landslides in the mountain region to the north. The number of aftershocks at Gifu in 2 years was 3,365, of which 10 were violent and 97 were strong. From these data Omori derived his well-known curve of decline of frequency of aftershocks. From fallen stone lanterns he estimated the maximum acceleration at 0.4 g. Earthquakes have been few in this region since the aftershocks ceased. Since the epicenter was distant from the sea, this was one of the very few great Japanese earthquakes that was unaccompanied by a tsunami.

The Japanese Government centered at Kyoto from 794 to 1868. The records kept make it certain that Kyoto and its port, Osaka, have had no great earthquakes in their vicinity. From 1480 to 1820 the most important were in 1596 (No. 2 in table 1), and in 1854, south of Lake Biwa. A destructive earthquake in 1899 at Osaka is mentioned by Davison. It should be said here that yet other destructive earthquakes are obviously expected by the Japanese, since the imperial palace at Kyoto, where the emperors are crowned, was strengthened in recent years. A prominent Japanese seismologist expressed such a view to the writer at Osaka in 1926. The damage at Osaka due to earthquakes in region II must not be overlooked.

The Tazima, 1925, and Tango, 1927, earthquakes strictly belong to region V, but they are remote from others in that region and are near the rest of region IV, and the Tango earthquake bears some resemblance to the shock of 1891. The Tazima earthquake originating in Tuiyama Cove on the coast of the Japan Sea was destructive, damaging 7,500 houses and causing more than 400 deaths, but its chief interest lies in

the fact that no destructive earthquakes were listed earlier for that place. The same is true for the Tango region. A hydrographic survey revealed no change in depth of the adjacent sea bottom.

The Tango earthquake of 1927 caused 10 times as much damage as the Tazima earthquake, and in the epicentral region the severity was of the first rank, the acceleration being estimated at 0.5 g. Though Tango was a center of the silk industry, the population was not so great as that of Tazima and this reduced the losses. The earthquake was remarkable for the short interval of 3 seconds from the time it was first perceived until it exerted a force sufficient to throw down buildings. There was no time to escape, and many of its victims were crushed. The town of Minoyama established a record even for Japan: only 10 out of 998 buildings survived, and 1,122 persons were killed. Fires were started from 15 centers, and no action was at once taken to put them out.

The earthquake was associated with visible fault slipping, which was studied with great care. The Gomura fault extends from the coast to the southeast, and, partly discontinuous, its fault slips, en échelon, for a distance of 11 miles, having a maximum horizontal change of about 9 feet. The greatest vertical change observed was only 27 inches. There was evidence from repeated hydrographic surveys that the fault extended seaward with greater vertical change than on land. The Yamada fault, nearly at right angles to the Gomura fault, is visible for 4.7 miles, but probably is 18 miles long. Its maximum vertical change was 28 inches. There was some permanent uplift of the coast. The epicenter of the aftershocks were studied in relation to block faulting. The height of the tsunami was about 5 feet. The deduced acceleration was 0.4 or 0.5 g.

Region V. Japan Sea coast of Honshu, except Tazima-Tango.—Only the earthquakes listed in table 1 will be considered, and they will be divided into three subgroups (A-C) for geographical convenience. Preseismic tilt is characteristic of many of these earthquakes, and this was the more readily detectable because the occurrences were near a shore with a maximum tidal range of about 1 foot.

A. North of latitude 39°. Included here in order of descending latitude are the earthquakes of 1793, 1704, 1694, 1810, 1939, 1914, and 1804. The western Tugaru earthquake of 1793 was noted for preseismic tilt. The land rose 3 to 6 feet, 4 hours before the earthquake. The extraordinary ebbing of the tide that accompanied this was regarded as warning of a tsunami. The inhabitants rushed to higher ground. Then came a violent earthquake, and the people, fearing landslides, rushed back to the beach, so that some were drowned by the tsunami even though it was moderate and otherwise did little damage. There

was a permanent uplift over a distance of 12 miles, with a maximum of 10 feet.

The 1804 Kisakata earthquake.—Mount Tyokai had an eruption a few years before and was still active, but without apparent relation to the earthquake. Before the shock the Kisakata Lagoon afforded picturesque scenery with a radius of a mile and an average depth of $6\frac{1}{2}$ feet. A permanent uplift of 10 feet eliminated the lagoon. At Kotaki, $2\frac{1}{2}$ miles to the southeast, there was subsidence of $4\frac{1}{2}$ feet, which altered the course of a stream. The other shocks listed were without special features, except that the one of 1939 was characterized by landslides and fissuring. Tsunamis, if any, were insignificant.

B. Latitude 39° to Toyama Bay. In this group are included the earthquakes of 1833, 1894, 1802, 1614, 1729, 1751, and 1666. In the Sado earthquake of 1802 there was quite heavy damage, but the special feature was the preseismic tilt. The earthquake occurred at 2 p. m. At the town of Ogi an extraordinary ebbing of the tide was noted about 10 a. m., a slight shock occurring at that time. The land rose about $3\frac{1}{2}$ feet, and as in the 1793 earthquake a tsunami was expected, but it did not arrive. The permanent uplift of about $6\frac{1}{4}$ feet was noted at Ogi and the distance over which there was uplift was nearly 15 miles.

C. Meridian 134° to the tip of Honshu. In this group are included the earthquakes of 1943, 1711, 1872, and 1676. The earthquake of 1943 appears to have been severe and felt over a large area. According to first reports by radio, many persons were buried in the debris at Totori and there was minor damage at Kobe, Osaka, and Hiroshima. These reports of damage were later denied, but seismograph records at a distance confirmed the first reported intensity. In the Hamada earthquake of 1872 there was an uplift of the shore amounting to $6\frac{1}{2}$ feet, 30 minutes before a widely felt shock. Fishermen began to gather stranded fish and shells on a bared narrow bar joining the shore with an islet. Immediately after the shock they rushed to higher ground and escaped the moderate tsunami which followed. On one side of a line through Hamada there was permanent upheaval to a maximum of $6\frac{1}{2}$ feet, and, on the other side, depression amounting to $3\frac{1}{2}$ feet, the total distance affected being about 12 miles. There were foreshocks with noise 4 or 5 days before the earthquake, and two on the same day.

Region VI. Interior of Honshu.—The list includes the earthquakes of 1766, 1896, 1611, 1659, 1828, 1714, 1847, 1858, and 1905 (on the Inland Sea). The Sinano earthquake of 1847 was featured by thousands of landslides and many villages were buried. The largest of these slides blocked the river Saikawa, forming a lake 17 by $2\frac{1}{2}$ miles at its widest point. At the end of 19 days the dam gave way and everything along the banks of the lower valley was swept away, including 4,800 houses and 28 persons. In the Hida earthquake of

1858 there was a similar occurrence. The detritus dammed the river Zyogwanzi; the dam held for 49 days and then broke, flooding the lower valley for 70 miles and drowning 148 persons. Other shocks listed for region VI have no known features of special interest.

Region VII. Kyushu Island.—The list includes the earthquakes of 1596, 1792, 1889, 1922, and 1914. In the earthquake of 1596 the island of Urya-zima near Oita, with an area of $1\frac{1}{2}$ square miles, sank beneath the sea to a depth of 30 to 40 fathoms, two-thirds at once and the rest later. In 1792 there was a great eruption of the volcano Unzen-dake. This began in February. On May 1, possibly as a result of an earthquake, there was a great avalanche which produced great water disturbance with heavy loss of life. It is possible that this should not be listed as a severe earthquake. In 1914 there was a great eruption of the volcano Sakurijima. The strongest earthquake, on January 12, was probably of volcanic origin though unusually severe for such a shock. Buildings of soft material and fence walls were thrown down. The other shocks listed for region VII were probably of volcanic origin.

FORMOSA EARTHQUAKES

Formosa has suffered severely from earthquakes, largely because of the type of buildings, heavy but weak. Omori has listed 18 shocks including 2 to 5 of the list from 1655 to 1906. In the shock of 1862 more than 1,000 persons were killed. In 1867 a wave swept the harbor of Keelung, northeast of Formosa; great landslides occurred. In the earthquake of March 17, 1906, there was fault slipping 6 feet vertical and 6 feet horizontal. (See pl. 3, fig. 2.) There were sand eruptions and cracking of the ground. The shock of April 14, centering 10 miles from the March earthquake, was not accompanied by surface slipping.

TABLE 2.—*Destructive earthquakes in Formosa, 1771-1943*

No.	Yr.	Mo.	Day	Lat. N.	Long. W.	Houses destroyed	Deaths	Locality and remarks
1	1771	IV	24	24.5	124.5	-----	9,400	Isigaki-zima T.
2	1862	VI	6	24	121	-----	1,000+	Kagi.
3	1867	XII	18	-----	-----	-----	200+	Keelung T.
4	1904	XI	6	-----	-----	611	145	Toroku, Kagi.
5	1906	III	17	-----	-----	6,769	1,258	Kagi.
6	1906	IV	14	-----	-----	1,794	17	Kagi, Ensuko.
7	1917	I	5	-----	-----	130	50	Horisya.
8	1935	IV	21	-----	-----	17,907	3,276	Taityo, Sintiku.

For explanation of terms, see table 1, p. 202.

SOME LESSONS FROM JAPANESE EARTHQUAKES

The Japanese have long wished to predict earthquakes, probably never more than now. They have studied crustal movements by re-

peated triangulation and leveling, long-continued and preseismic tilt, and all kinds of periodicities. The earthquake of 1930 in northern Idu indicates how difficult it is to correlate crustal movement with earthquakes. A case has been made from occurrences in earthquakes of the Japan Sea coast for preseismic tilt, from 30 minutes to 5 hours before the earthquake. The study of periodicities has not brought significant results, except that there is an interval of several centuries between major earthquakes of any region. The outstanding examples of great success and great failure in prediction are credited to Omori. After the California earthquake of April 18, 1906, he predicted that the next great shocks in the circumpacific belt would occur in South America and Alaska. On the same day, August 16, 1906, there were great earthquakes in Valparaiso, Chile, and the Aleutian Islands. In the spring of 1923, Omori expressed the view that there would be no great earthquake in the Kwantō region for many years, and the great shock came on September 1.

The Japanese have gone in strongly for earthquake-resistant structures, and miscellaneous measures have been taken.⁷ Heights of buildings have been restricted, simple structures insisted on, and water supply that is not likely to be affected by earthquakes has been established in Tokyo at least. The effectiveness of these measures has not been tested, and the description of the 1923 shock has brought out many things to guard against.

⁷ Willard Price, *Unknown Japan*, Nat. Geogr. Mag., vol. 82, pp. 225-252, 1942.



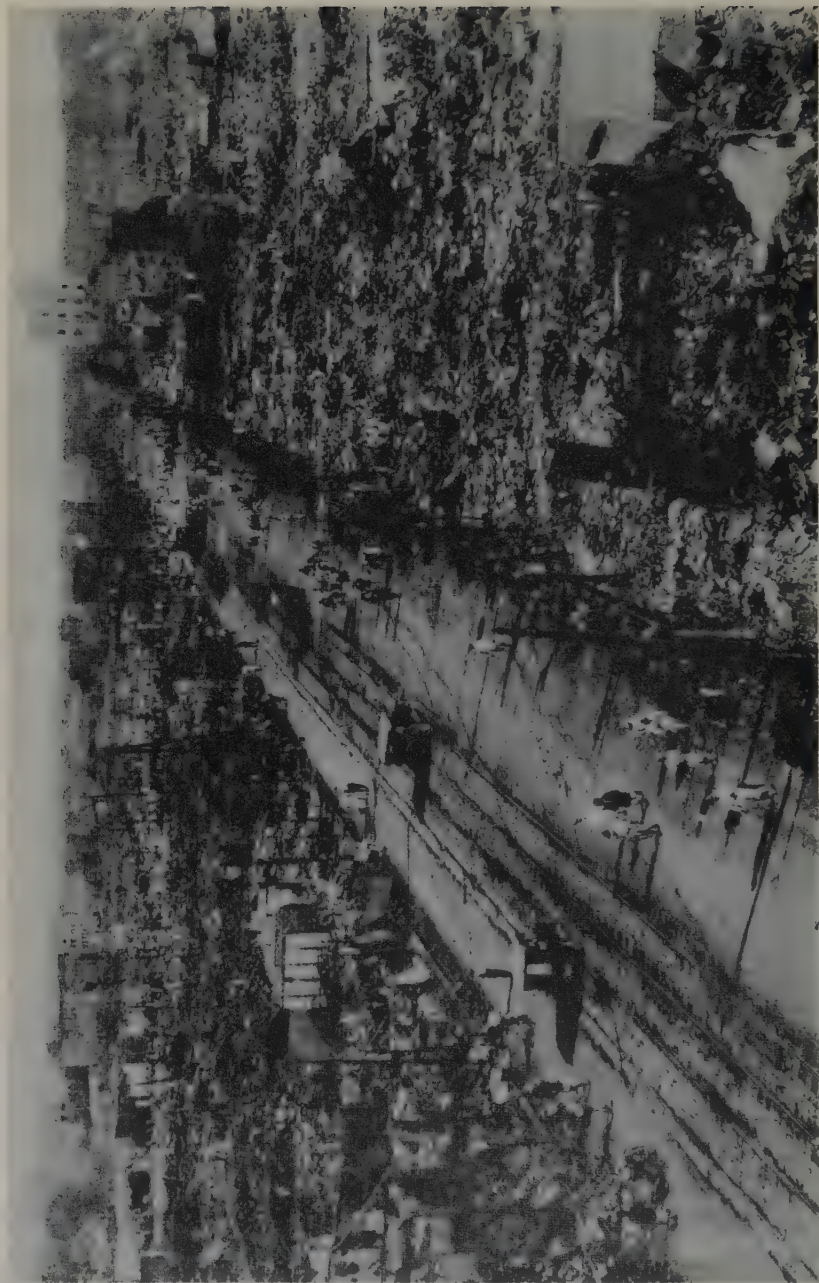
1. FISHING VESSEL LEFT IN STREET BY TSUNAMI.

(From Bulletin of the Earthquake Research Institute, Tokyo Imperial University.)



2. STREAM BLOCKED BY ROCK SLIDE, EARTHQUAKE OF 1923.

(From "The Great Earthquake of 1923 in Japan," compiled by the Bureau of Social Affairs.)



RUINS LEFT BY EARTHQUAKE AND FIRE IN TOKYO, 1923.
(From "The Great Earthquake of 1923 in Japan," compiled by the Bureau of Social Affairs.)



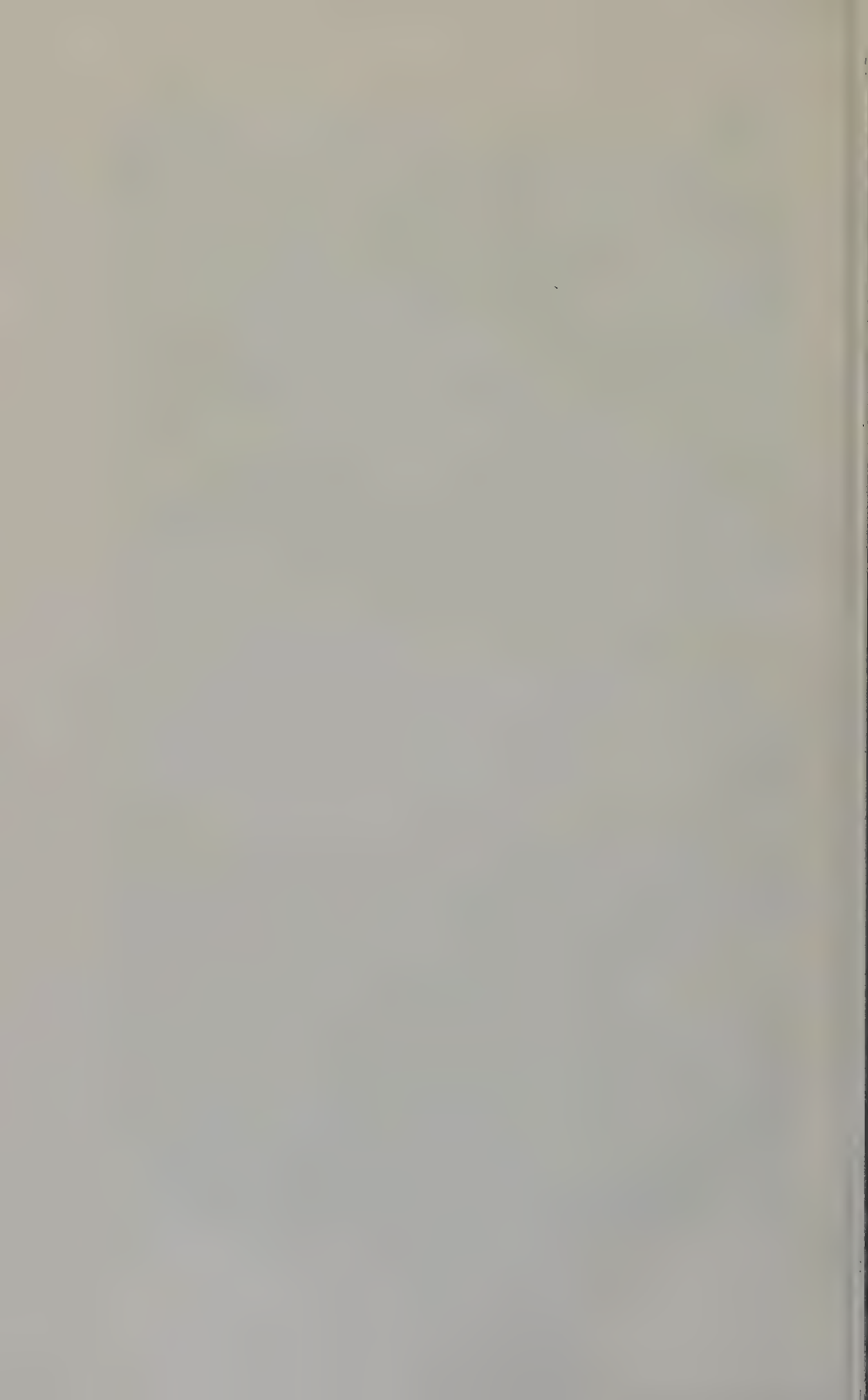
1. DAMAGE IN SUBURB OF NAGOYA, MINO-OWARI EARTHQUAKE OF 1891.

(After Kikuchi.)



2. SLIP ALONG FAULT IN FORMOSA, EARTHQUAKE OF 1906, 6 FEET VERTICAL AND 6 FEET HORIZONTAL.

(After Omori.)



CONQUEST OF THE NORTHWEST PASSAGE BY R. C. M. P. SCHOONER "ST. ROCH"¹

By J. LEWIS ROBINSON

Geographer, Bureau of Northwest Territories and Yukon Affairs, Ottawa

[With 12 plates]

The search for the Northwest Passage forms an intriguing chapter in the history of Canadian exploration. The stories of early navigators who faced the dangers of polar pack ice in tiny wooden sailing ships, traveling, with doubtful compasses, along uncharted coasts, are accounts of hardship, courage, and perseverance. The fruitless quest for a route north of the North American mainland to the wealth of the Far East resulted in the exploration and charting of most of the numerous Arctic islands of Northern Canada. As more and more knowledge of this inhospitable region was obtained through exploration, the trading incentive behind the search for a northwest route waned in the light of geographic facts which showed the route to be commercially impractical.

In the sixteenth century Europe began to look toward the new continent to the west, and expeditions from England, Spain, Portugal, and France groped their way along the unknown coasts. At first this new land mass was regarded chiefly as a barrier, of little value in itself, blocking the route to the fabled riches of the East. Exploration was interested in a way around or through it, and in 1576 Martin Frobisher first entered the eastern Arctic seeking such a route. John Davis, who followed Frobisher's lead, reached Baffin Bay before the end of the century and noted several westward openings on the barren rocky coast.

Exploration in the early seventeenth century was sidetracked by the broad opening of Hudson Strait, and many years were spent in defining the limits of extensive Hudson Bay. The failure of several expedi-

¹ Article prepared at the Bureau of Northwest Territories and Yukon Affairs, Lands, Parks, and Forests Branch, Department of Mines and Resources, Ottawa, based on interviews with and reports from Staff Sergeant (now Subinspector) Henry A. Larsen of the Royal Canadian Mounted Police, and published by permission of the Commissioner, Royal Canadian Mounted Police. Reprinted from the Canadian Geographical Journal, vol. 30, No. 2, February 1945, by permission of the publishers and the Administration of the Northwest Territories, Ottawa, Canada.

tions to find openings west of Hudson Bay dampened interest in the search in this direction, and for a time exploration was neglected.

After the Napoleonic Wars, expeditions from the British Navy renewed the search for a northern route through the sea reported north of America. Edward Parry entered Lancaster Sound in 1819 and twisted through eastward-moving ice floes as far as Melville Island before freezing his ship in for the winter. The next season ice choking the channel to the westward prevented further progress, and Parry returned to England. In 1821 Parry tried the southern route through Hudson Strait and Foxe Channel, and reached the entrance to Fury and Hecla Strait before being stopped by ice. Later attempts to pass through this strait also failed, and it has not yet been navigated by other than Eskimo mariners. Further exploration by John Ross, beginning in 1829, confirmed the existence of Boothia Peninsula extending north from the mainland of Canada and discouraged all hopes for a passage through this region. Since Ross did not see Bellot Strait, the strategic opening to the west, it was believed that Somerset Island was part of this long barrier peninsula.

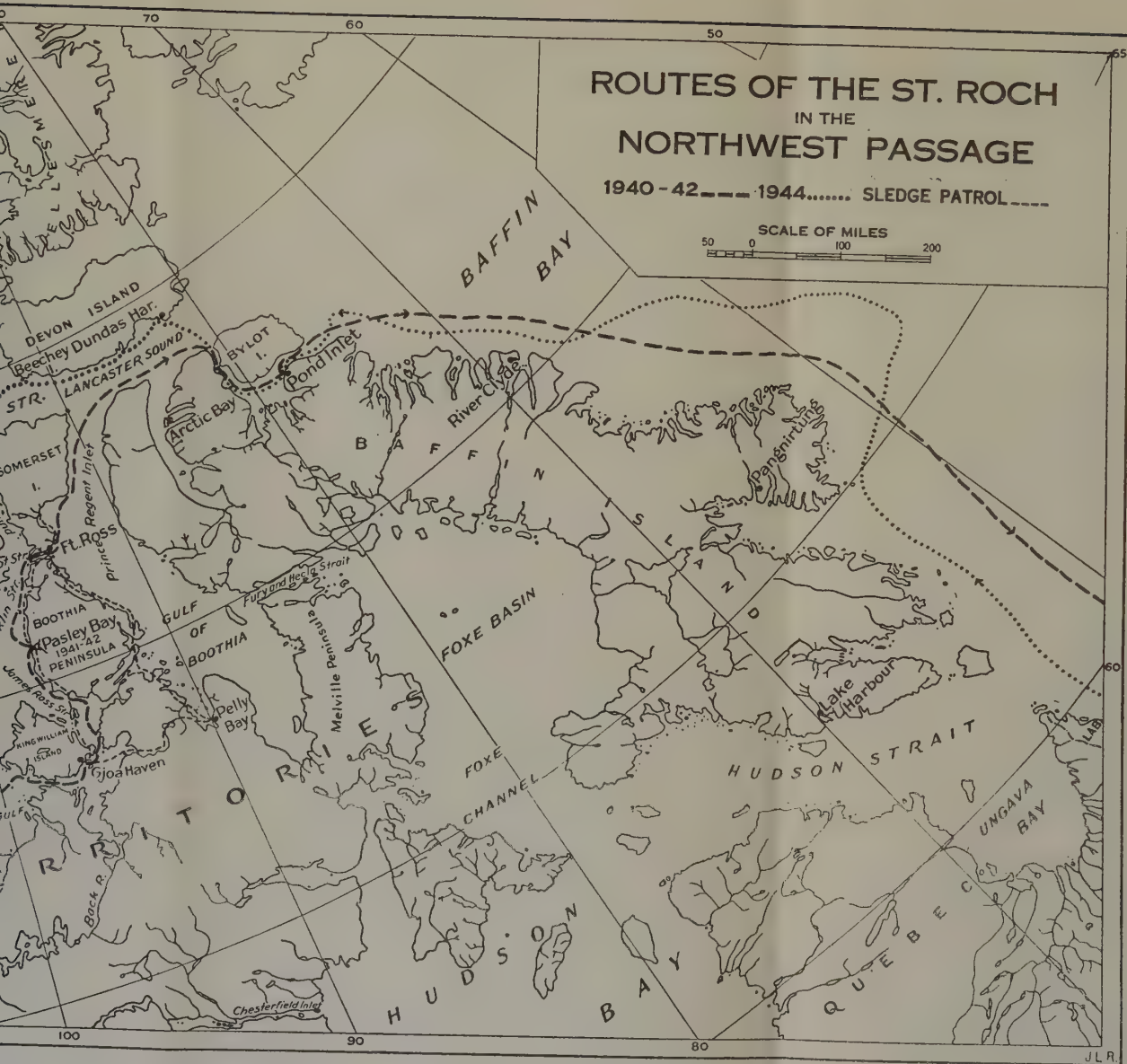
In 1845 Sir John Franklin led a British naval expedition into Lancaster Sound, and, after being stopped by ice in Barrow Strait, wintered at Beechey Island, the southwestern corner of Devon Island. The next year he continued westward and was lost, never to be seen again. Despite the fact that 16 rescue expeditions entered the Arctic from both the east and the west, discovered 6,000 miles of new coast line in their search, and covered about 40,000 miles by winter sledge trips, Franklin's fate remained a mystery until M'Clintock brought out some clues in 1859. This extensive search well illustrated the vastness of the Canadian Arctic. Many famous explorers, whose names are now commemorated on our maps, traveled widely by small boat in summer and by sledge in winter, and their mapping brought forth the first definite outlines of the Arctic islands. All their accounts lay stress on the short navigation season after the land-fast ice breaks up, on being obstructed by extensive masses of pack ice moving eastward from the Arctic Ocean through the many channels of the Arctic islands to Baffin Bay and the North Atlantic, and on an early freeze-up followed by a severe winter, with sledges as the only means of travel.

In 1854 the long-sought Northwest Passage was finally traversed by Captain M'Clure and part of his crew. They abandoned their ice-bound ship north of Banks Island in 1853 and sledged eastward to meet Captain Kellett at Dealey Island. The next spring M'Clure sledged to Beechey Island and was brought out from there by ship. When the news that the difficult route had been found was combined with geographic information which was reported on ice and navigation



Map of routes taken by "St. Roch"

FIGURE



completing the Northwest Passage.

conditions by the many expeditions, enthusiasm for the Northwest Passage declined among explorers. In the meantime, commerce now knew safer and more dependable routes to carry the world's merchandise, and no longer encouraged interest in the Passage.

The Northwest Passage, which had brought so many ships to destruction in the ice during three long and arduous centuries of polar exploration, remained unconquered by any one vessel until the beginning of the present century. In 1903, Roald Amundsen, Norwegian Arctic adventurer, entered Lancaster Sound in a small 47-ton vessel, the *Gjoa*, and took a route southward into uncharted Peel Sound, between Somerset and Prince of Wales Islands. He navigated as far as southeastern King William Island, where his party spent two winters at Gjoa Haven (Petersen Bay), studying terrestrial magnetism near the North Magnetic Pole on western Boothia Peninsula. In leaving the Arctic, Amundsen sailed westward through Queen Maud and Coronation Gulfs but was caught in the ice near Herschel Island, where he passed his third winter in 1906. Next summer he and his crew continued westward, becoming the first persons to navigate the Northwest Passage successfully from east to west in a single ship.

Within the modern period the Hudson's Bay Co. has experimented with the use of the northern route to bring supplies to its far-flung northern trading posts. In 1928 the H. B. C. schooner *Fort James*, drawing 9 feet of water, entered the western Arctic from the east through Lancaster Sound and Peel Strait and brought supplies to the Gjoa Haven trading post on King William Island. After spending two winters there the *Fort James* returned to the eastern Arctic via the same route. This was the first commercial use of part of the passage, but when the *Fort James* was sent to the western Arctic in 1934, she traveled via the Panama Canal.

In 1937 the Hudson's Bay Co. icebreaker *Nascopie*, carrying the Canadian Government Eastern Arctic Patrol, opened the trading post of Fort Ross at the eastern end of Bellot Strait, and here met and exchanged freight with the small H. B. C. schooner *Aklavik*, which came up from King William Island. Thus Bellot Strait, which had five times defied Captain M'Clintock and his *Fox* in 1858-59, became the meeting place between the eastern and western Arctic on the Northwest Passage. Shallow seas along the western section of this route, however, limited the size of boats to small schooners like the *Aklavik*, causing the route to be of little economic value, and the scheme was dropped in 1940.

The ship which was to make history in the Northwest Passage, the R. C. M. P. schooner *St. Roch*, was built in 1928 and entered the western Arctic around the Alaskan coast. In the following years the 80-ton two-masted vessel traveled along the western Arctic coasts and islands

as a "floating police detachment," carrying supplies and doing routine patrol work without fanfare, through the same difficult ice conditions which had cost so many ships and lives among the early explorers. These hardy adventurers were able to brave only one or two winters in the Arctic, but the sturdy *St. Roch* has spent 11 of her 16 years frozen into the ice of some Arctic harbor. In 1928-29 she wintered at Langton Bay. Four successive winters, 1930-34, were spent at Tree River, in Coronation Gulf, and three winters, 1935-37 and 1938-39, were passed frozen in at Cambridge Bay. Aided by modern equipment and radio communication, the R. C. M. P. boat has been performing feats of Arctic ice navigation equal to those history-making voyages of less than a century ago. But to Staff Sergeant Henry A. Larsen, who has been the unassuming captain of the schooner during all these years, this difficult work of navigation and long winter dog-sled patrols are the usual routine in maintaining law and order in the Canadian North.

On June 23, 1940, the *St. Roch* left Vancouver, British Columbia, beginning the historic voyage which was to make the 80-ton schooner the first ship to complete the elusive Northwest Passage from west to east. The voyage northward through the Inside Passage and across the North Pacific to the Aleutians was uneventful. The *St. Roch* entered Bering Sea through Unimak Pass and anchored at Akutan Harbor to check her engines and fill the fresh-water tanks. The schooner continued to Dutch Harbor in the Aleutians on July 8 to load a supply of fuel oil for the diesel-powered engines. Adverse weather, with strong winds, rain and fog, was met in crossing Bering Sea and, after stopping at Teller Harbor for a day, the *St. Roch* passed through Bering Strait in a dense fog and entered the Arctic Ocean on July 17.

On July 23, the *St. Roch* rounded Point Barrow spit and met the first loose-scattered ice floes. By evening the blocks had become more numerous, and the *St. Roch* began the familiar task of slowly "working the ice"—twisting and turning from one lead to another opening, edging around large floes and pushing aside small blocks, drifting with the pack and waiting for a lead to appear; Larsen and the *St. Roch* had been doing this patient work in partnership since 1928. Progress was slow and it became apparent that this was going to be a bad year for ice along the northern Alaskan coast.

Ice conditions are unpredictable in the Arctic, and are greatly dependent upon prevailing winds. The polar pack ice, which moves in a general clockwise direction in the Arctic Ocean, presses southward against the Alaskan coast. In years when prevailing winds are easterly or southerly, the ice is moved westward and leaves an open strip along the coast; but northerly winds will pack the floes against the

shore, impeding or blocking passage. Although this northern route was formerly used by whalers, many were lost during bad years, and since 1936 only the H. B. C. schooner *Fort Ross*, in addition to the *St. Roch*, has entered the western Arctic via this route. Small schooners have more success along the Alaskan coast because they can travel close to shore inside of the ice which grounds in the shallow coastal water. The only large ship to attempt this route, the H. B. C. icebreaker *Baychimo*, after a few successful trips was caught in the ice off Point Barrow in September 1931, and abandoned.

For 18 days the *St. Roch* struggled in the pack ice, east of Point Barrow. During much of this time the schooner had to be continually tied up to large floes for protection, and movement was mainly concerned with preventing the ship from being crushed. The weather was constantly foggy, further curtailing chances to see leads. At one time the *St. Roch* was able to anchor close to shore near Beechey Point, but as the ice began to close in again Larsen had to put the schooner back into the pack to avoid being shoved ashore. It was then moored to a grounded floe for 2 days so as not to lose distance by being pushed westward during a furious northeasterly gale. On August 2 the police vessel resumed working eastward and reached Cross Island before being caught once more. Northwest winds jammed the ice against the shore and pressed hard against the boat, so that on August 10 Larsen had to start blasting the ice in order to work free. After each blast the schooner charged into the opening and finally reached open water near shore. Thereafter good progress was made eastward, although the vessel scraped bottom several times. Barter Island was passed on the morning of August 11, and very little ice was encountered between there and Herschel Island.

After loading coal and other supplies, the *St. Roch* left Herschel Island on August 18 and crossed Mackenzie Bay to Port Brabant (Tuktoyaktuk or Tuk-tuk). From this harbor the police schooner continued her normal routine patrol work of carrying supplies to the various R. C. M. P. detachments in the western Arctic. Bad weather, fog, and strong winds caused several delays in the eastward trip to Coppermine and Cambridge Bay, and it was not until September 16 that the schooner returned to Coppermine with her freighting duties finished.

Captain Larsen had originally hoped to proceed through the Northwest Passage via Prince of Wales Strait between Victoria and Banks Islands after completing the freighting work, but the delays caused by ice and bad weather discouraged any such attempt so late in the season. A decision was then made to winter either on Banks Island or at Walker Bay on central west Victoria Island, and to be ready to navigate the Passage early the next summer. The *St. Roch*, therefore, left Coppermine on September 19 and went to Holman Island and thence to DeSalis Bay, Banks Island.

September 25 was spent in examining the enormous harbor and surrounding country at DeSalis Bay, but when Larsen noted high ridges of rock and gravel pushed up along the shore, indicating heavy ice pressure during break-up in the spring he considered it unwise to winter here. Since no other good harbors were known in the area, the *St. Roch* sailed for Walker Bay, where the explorer, Collinson, had wintered in 1851-52. The vessel had a total of 5,240 miles to show for a season's work when she was anchored in the southeastern part of this bay.

A continuous strong east wind blew during most of October and prevented Walker Bay from freezing over until October 30. It was the latest freeze-up known in this area, and, if Larsen had had any way of knowing that it was to be so delayed that year, it is possible that he might have been able to make his way immediately through the Passage to the eastern Arctic. The vagaries of Arctic weather are unpredictable, however, and what is done in one year may not be possible in another. After the schooner was frozen in, a framework was constructed and the deck was completely housed over with canvas.

During the winter of 1940-41 the *St. Roch* detachment made several normal patrols through the area, visiting native camps to investigate Eskimo conditions and welfare, registering vital statistics and firearms, and generally carrying out the many other duties of the R. C. M. P. in supervising this vast Arctic region. As is customary, travel was by Eskimo dog team and sled, and the nightly shelter was a snow house of their own construction. Short patrols totaling 990 miles were made to Holman Island for mail, to Minto Inlet, to Prince of Wales Strait and inland on Victoria Island. One especially long patrol of 41 days, covering about 600 miles, was made for the purpose of visiting the prosperous Eskimo camps on the western side of Banks Island.

During the spring, when days became longer, the vessel and equipment were scraped and painted and all machinery was examined and overhauled. The ice in the harbor began to break up in July, but westerly winds kept Walker Bay blocked with floes for some time. On July 31, Larsen decided to try to work his way out, and, after much maneuvering, finally reached the trading post and mission at Holman Island. Here duty intervened, preventing the schooner from attempting the Passage through Prince of Wales Strait. A native boy had been accidentally shot and needed to be taken to hospital at Aklavik. Large and numerous ice floes, foggy weather, and a storm off the mainland coast made progress slow, and the harbor at Port Brabant was not reached until August 5. Whereas Amundsen Gulf had been free of ice until very late in the preceding year, during the summer of 1941 floes jammed the northern part of it throughout the whole season. Thus does the natural environment limit planning in the western Arctic.

Supplies were loaded into the *St. Roch* at Port Brabant on August 8, and the vessel left for Coppermine to fulfill her freighting duties. Scattered ice, rain, and fog made travel to Baillie Island difficult, while large unbroken floes extending eastward to the horizon forced the schooner to travel along the shallow shores. Open water was finally reached in Dolphin and Union Strait, and the vessel arrived at Coppermine on August 12. Coronation Gulf favored the *St. Roch* with good weather and open water, and she anchored in Cambridge Bay early on August 16.

Since the detachments had now been given their year's supplies, Larsen decided to continue eastward and attempt the Passage around King William Island and through Bellot Strait. On August 19 he left Cambridge Bay, but strong westerly winds, rain, and fog were ill omens. Larsen was forced to anchor in the shelter of Lind Island, and was held there until August 24. The compass was now useless, owing to the proximity of the Magnetic Pole, and navigation through island-studded Queen Maud Gulf was by experience and seaman's "sixth sense." The *St. Roch* proceeded cautiously toward Simpson Strait, south of King William Island, taking soundings continually, since no vessel of her draught (121½ feet) had ever been in these waters. Because Simpson Strait is narrow and full of small rocky islands, Larsen sent the motor launch ahead to sound a course. The bottom was uneven, with depths averaging from 6 to 8 fathoms, and with several shallow places of 3 fathoms. On August 26 the vessel remained at anchor during a thick fog. The next day she proceeded carefully and reached Gjoa Haven (Petersen Bay) in the afternoon.

The seafaring policemen left this trading post on August 30 and were soon inching their way through shoal water and strong tide rips in Rae Strait. A northwesterly storm, accompanied by hail and snow, forced the schooner to the coast in the shelter of Mount Matheson, on the eastern tip of King William Island. Here she pitched and rolled for a day before proceeding northward, with one man continuously sounding with the lead and another at the masthead on the lookout for shoals. East of Matty Island large shoals, which rose abruptly from 10 to 21½ fathoms, forced the schooner to seek deeper water.

In the narrowest part of James Ross Strait, northeast of Matty Island, the *St. Roch* was stopped by a solid wall of grounded ice extending from shore to shore. Since the vessel was not built or powered to break such a barrier, she was anchored nearby to wait for the tide to change direction. Early in the evening the ice began pushing southward in a strong current. The only shelter available was in the lee of a small rocky islet only slightly larger than the schooner herself. A snowstorm shut off visibility, and throughout

the night the *St. Roch*, with both anchors out, was continually battered and pushed by grinding ice blocks, and the little company on board did not know whether they were still near the islet or were caught in the ice. The morning of September 2, however, found them still there and undamaged, and when a south wind began pushing the ice northward they moved along with it.

On September 3, improved weather allowed the *St. Roch* to proceed northward between the coast and the ice. The low land was now snow-covered, and when visibility became poor the white shore could not be distinguished from the grounded ice. During the day the wind changed to the west, gradually moving the ice closer to the coast. It became apparent that there was a definite danger of being caught and crushed. Fortune was with the valiant ship, however, for Pasley Bay, a long inlet, erroneously shown on the charts as a broad bay, appeared ahead, and the *St. Roch* was forced into it.

The next morning its crew made a trip to a nearby hill to look westward over the ice of Franklin Strait and M'Clintock Channel. It was jammed against the coast as far as could be seen, and extended in a jumbled mass to the horizon. In the afternoon large floes began to shove into the inlet, and the *St. Roch* had to move farther in. Soon the ship was completely surrounded by heavy ice and could no longer maneuver. On the morning of September 6 the ice carried the vessel against a shoal in $1\frac{1}{2}$ fathoms, turned the schooner twice, listed it to alternate sides, and then pushed it completely over the shoal, dragging two anchors and 90 fathoms of chain.

Heavy snowfall and variable winds continued, and the *St. Roch* remained locked in the ice until September 9, when deep water was found in an opening close to the shore. On September 11 the ice movement ceased. New ice soon formed rapidly in the open places, and the whole inlet froze over solidly. As it was now impossible to escape, the ice was cut away from the ship, which was anchored farther off-shore so as not to be grounded in the spring. Preparations were then made to spend the winter in Pasley Bay, close to the North Magnetic Pole on Boothia Peninsula, and the news was radioed outside. The schooner had traveled 1,660 miles during the summer. The season was still early by normal standards, and Bellot Strait and the Northwest Passage were only 100 miles away, but the fickle Arctic had again frowned on the *St. Roch*.

The stranded R. C. M. policemen had an important task to perform during the winter of 1941-42. In the taking of the census of the Canadian Arctic areas, their job was to meet as many as possible of the Canadian Eskimo in this little-visited region. In order to do this Larsen traveled by dog team to the trading post at Fort Ross in early December and obtained information as to the location of the native

camp sites in the area. In early January Constable Chartrand patrolled to King William Island to prepare a fish cache for the long spring census trip, and also to bring back additional winter clothing made by the natives for the detachment. Toward the end of February, Sergeant Larsen and Constable Hunt, having picked up a native guide, left their winter headquarters on the *St. Roch* for an epic patrol which was to cover 1,140 miles and extend over a period of 71 days. They traveled north to Fort Ross and beyond to Creswell Bay, then southward along the east coast of Boothia Peninsula to the mission at Pelly Bay. After spending Easter there, they traveled westward to Gjoa Haven, King William Island, where both were laid up for 14 days with influenza. This illness curtailed the patrol, and they returned to the *St. Roch* on May 6.

The winter weather at Pasley Bay was quite different from any other that Sergeant Larsen had known previously in the Arctic. Continued fog and snowfall with variable winds made visibility poor, while sudden changes in temperature from 30 below zero to zero and back again within a short time made it difficult to become acclimated. As summer approached it became apparent that the ice was not going to break up early in this region. It was still packed solidly outside the inlet, and pressure ridges, 50 to 100 feet high along the coast north of Pasley Bay, showed the results of enormous ice forces. Since the ice was to remain that year there was virtually no navigation season for the west side of Boothia Peninsula during the years 1941-42.

The *St. Roch* and police crew spent 11 months at Pasley Bay. On August 4, fresh water draining into the harbor loosened the ice and allowed them to move out of the inlet. On the shore behind they left a new cairn and grave. On February 13, Constable Chartrand had had a sudden heart attack and died almost immediately; his death was the only tragedy of the trip.

Captain Larsen navigated shoreward of the main pack ice and made 15 miles northward along the coast before being stopped by a solid mass of floes. He then put the vessel into a small lead extending westward to await a break-up. The opening closed, however, and the schooner was caught and held there helpless for 20 days. On several occasions, while they were beset, severe pressure lifted the boat high in the ice and threatened to turn her over. At these times charges of black powder were set off near the vessel to relieve the pressure, while the police crew worked with ice chisels to keep free the propeller and rudder. An easterly wind carried the schooner farther and farther away from the coast.

On August 24 a strong northerly gale split the ice and opened a long lead south from one of the rocky Tasmania Islands. It took two anxious days for the *St. Roch* to break through the short distance to

the lead and then to follow the twisting, grinding opening to the safety of a deep anchorage among this small group of high islands. A strong current set back and forth through the islands, with the regular 5-foot tide, and on August 29 Larsen decided that the leads looked promising. They worked northward to Dixon Island and then found easier going to Bellot Strait.

With the Northwest Passage practically in their grasp, tragedy almost struck the *St. Roch* and crew in Bellot Strait. The western end of the strait was free of ice, but the tide was changing direction to the eastward as the vessel entered. The ice from Peel Sound was carried in behind them. Half-way through the strait, Larsen suddenly saw that an ice jam had formed ahead from shore to shore. They could not turn back and were headed for a large, thick, grounded floe. Then, just as they were about to crash and be wrecked, a smaller floe hit the larger one and broke off its southern half. The next moment the *St. Roch's* prow went into the widening crack and she drifted forward between the two floes.

The *St. Roch* left Fort Ross on September 2, surrounded by moving floes, and worked north in Prince Regent Inlet, with young slush ice already forming. The *Nascopie*, on the Eastern Arctic Patrol, was to have entered this inlet later in the month, but although she had reached Fort Ross successfully for five previous years, she was stopped this time by the ice which was already threatening the *St. Roch*. The hurrying schooner entered Navy Board Inlet and stopped at the Pond Inlet post on Northern Baffin Island to discharge stores and coal for the police detachment and to pick up Constable Doyle. On September 10 it left this eastern Arctic post and traveled through numerous bergs and storms southward along the Baffin Island and Labrador coasts.

After stopping at Labrador, Newfoundland, and Sydney, Nova Scotia, the *St. Roch* and crew arrived in Halifax on October 11, having traveled 2,840 miles en route during their third summer season. The historic news that the *St. Roch* was the first ship to complete the west-to-east voyage through the Northwest Passage in Northern Canada was then released. The trip of 27½ months bettered Amundsen's time, and, with improved weather and ice conditions, it might well have been less. To Staff Sergeant Henry A. Larsen this historic feat was an achievement of which to be proud, but nothing about which to become excited. He and his police crew had been traveling around amid the ice floes of the western Arctic in good and bad seasons for 14 years and had conquered the Passage as a side activity while successfully carrying on with their other police duties. Larsen discounted his long winter patrols by Eskimo dog team and sled as something which the R. C. M. Police are doing every winter throughout the Arctic in keeping contact with our migratory Eskimo population.

During the 1943 navigation season the *St. Roch* had a change of scenery while patrolling the eastern Arctic detachments. She entered Hudson Strait after most of the ice had gone, and had little trouble in sailing around in this new region with no ice impediment except the huge bergs met off the eastern Baffin Island coast. The eastern Arctic, however, is not always so friendly.

During the spring of 1944 the *St. Roch* was provided with greater engine power, one mast was removed, and she was fitted with the luxury of a new gyrocompass. The R. C. M. P. were going to patrol another route through the Arctic islands as part of Canada's work in maintaining sovereignty over these barren, uninhabited islands, and the partnership of Larsen and the *St. Roch* was scheduled for another history-making voyage.

On July 22, 1944, the *St. Roch* left Halifax, but developed engine trouble which forced her to put in to Sydney. She left there on July 26, but had to moor again at Curling Cove, Newfoundland, to make further engine adjustments. On July 28, she put to sea once more, and thereafter had no further engine difficulties. Numerous bergs and thick fog were found off the Labrador coast, but Larsen navigated around icebergs just as efficiently as he worked through floes. Cape Chidley, the northern tip of Labrador, was passed on August 2, and the next day the patrol was greeted with the familiar sight of pack ice off Hall Peninsula, Baffin Island. The ice was broken, but tightly packed, and progress was impossible, so Larsen swung over to the usual open water off the Greenland coast on August 4. On August 6 he turned westward toward Baffin Island, and again met pack ice and fog slightly south of River Clyde. For several days the gyrocompass had been unreliable, and would suddenly change 10° to 20° ; finally it had to be ignored as useless. Larsen's navigation from then onward was by sight, experience, and the wavering magnetic compass.

In trying to work through the ice to travel near the coast off River Clyde, Larsen found that the land-fast ice had not yet broken up and he had to stay offshore. His difficulties were further increased by an amazingly strong mirage effect which made the leads difficult to pick out. Progress was stopped on August 9 by floes that were very large and unbroken, although only about 2 feet thick. Bylot Island was glimpsed through a thick fog that evening, but the *St. Roch* remained moored to a large floe off the entrance to Pond Inlet until August 12, when she slipped forward and anchored off the post settlement.

Detachment supplies were unloaded at Pond Inlet, and the police picked up a native, his family and 17 dogs. The Eskimo was quite willing to adventure into the unknown, and so, in case the *St. Roch* should be forced to winter, he was taken along to hunt food and aid in winter traveling with his dog team. The expedition left Pond

Inlet on August 17 and, proceeding up Navy Board Inlet, crossed Lancaster Sound to Devon Island. A strong southerly gale off Cape Warrenden caused the *St. Roch* to pitch a great deal before shelter was found in the lee of a large flat-topped iceberg. There it cruised back and forth until the storm subsided.

The *St. Roch* arrived at the former R. C. M. P. post at Dundas Harbor, Devon Island, on August 18, and found the unoccupied buildings in good condition. The patrolling schooner and police crew left the next day and followed along the high, cliffy coast until they came to a good harbor in a little-known 7-mile inlet (either Stratton Inlet or Burnett Creek). Here they found ruins of an Eskimo culture of several centuries ago; after building a cairn and depositing records of their visit, they departed. That evening (August 19) the first snow fell, heralding the coming winter.

Larsen and the *St. Roch* continued westward, but the coast line was usually hidden by frequent heavy snow squalls. The weather cleared near Maxwell Bay, Devon Island, and they saw a steep-walled coast with no beach and a flat-topped upland. A few bergs could be seen to the south, but otherwise Prince Regent Inlet was free of ice. On August 20, they arrived at historic Erebus Bay, Beechey Island.

Beechey Island is actually connected to Devon Island by a low spit which is dry at low tide. A narrow lowland at the base of the former high-cliffed "island" was the site of the winter quarters of several early Arctic explorers. Within recent times the site had been visited by one of Otto Sverdrup's sledge parties in 1902, by A. P. Low in 1904, by Captain Bernier in 1906 and 1908, and by the C. G. S. *Arctic* in 1923. Numerous police patrols from Dundas Harbor, and also the *Beothic*, carrying the Canadian Government Eastern Arctic Patrol in 1927 and 1928, called there to keep a watchful eye on the historic ruins. Except for part of the keel and a bit of planking, all that was left of the yacht *Mary*, placed there in 1850 by Sir John Ross, was the mast, which was stuck in the sand. Only ruins remained of the cache called Northumberland House, left by Commander Pullen of the H. M. S. *North Star* in 1854. A further search of the island revealed nothing of historic interest. Since the land was barren and desolate, with no fresh-water supply, the *St. Roch* proceeded from Beechey Island on the morning of August 22.

Wellington Channel was clear of ice as far as could be seen to the northward, but the first floes were met drifting eastward at Cornwallis Island. Larsen followed leads through the tightly packed floes, staying inside of the line of Griffith, Somerville, and Brown Islands, along the Cornwallis Island coast. Several walrus were seen in this area, and four were shot and brought on board to be used as dog feed. At other times, along the way, seals were shot to feed the

team of hungry Eskimo dogs. Since the ice was packed solidly to the south, Larsen turned north along Cornwallis Island as far as Cape Airy, where he found leads pointing westward toward Bathurst Island, the south shore of which was obscured by a heavy snowstorm. Despite being turned and buffeted by the ice, the *St. Roch* maintained a forward course, and Cape Cockburn was reached about noon on August 23. Here solidly packed floes blocked further progress. The tide set to the east, and the *St. Roch* was carried 20 miles back to Ackland Bay before anchoring close to shore. Larsen's difficulties were further increased by the failure of his magnetic compass, which had pointed fixedly at the bow of the schooner for several days. For the remainder of the voyage he had only his Admiralty charts and an amazing sense of direction upon which to depend as navigation aids. Even the sun was hidden by continuous snowstorms.

Early in the morning of August 24 the *St. Roch* once more slipped along the coast to Cape Cockburn and anchored, while a party went ashore to look for Captain Bernier's cairn. No trace of the cairn could be found, but numerous bear tracks in the area suggested that these curious animals might have scattered it. Larsen left an R. C. M. P. cairn near a conspicuous rock on the south side of the point and placed a record of their visit inside it for historical reference. From this high cape it could be seen that Viscount Melville Sound was filled with ice to the horizon. The ice was broken but tightly packed, and was pushed against the islands by a strong south wind. Ice was also being carried southward by currents through Austin Channel, west of Bathurst Island.

Since he could not proceed westward, Larsen decided to try a route north of Byam Martin Island. He experienced a great deal of trouble near Graham Moore Bay on western Bathurst Island, owing to the *St. Roch's* drifting southward with the current each time she was stopped by the ice. After patiently working back and forth from one small opening to another, shoving the floes when possible, or letting them drift by, the *St. Roch* made the north coast of Byam Martin Island on the evening of August 25. Here Corporal Hunt and a party went ashore to build a cairn and leave a record of the patrol. Because of a heavy snowfall, no observation of the surrounding land could be made, but fresh caribou tracks were seen.

August 26 began with clear weather and a fresh westerly wind. After rounding the northern tip of Byam Martin Island, the expedition found open water to the westward. Melville Island was soon sighted, near Consett Head, and the men saw a herd of 12 musk oxen grazing on the grassy lowland. Other herds of musk oxen were seen on the tundra farther south, proving that these protected animals, part of the remnant of the species, had survived on their isolated sanctuary.

Except for a long patrol by the late Inspector A. H. Joy of the R. C. M. P. to the island in 1929, no white man has visited Melville Island since Stefansson's party in 1917.

South of Griffith Point, Melville Island, where a cairn was built, the *St. Roch* was forced to travel slowly, owing to shoal water of 4 to 8 fathoms for 2 miles off the coast. At midnight the expedition anchored off Palmer Point, with still no ice in sight, and another record was deposited. An excellent harbor north of the point was examined the following morning, when thick weather discouraged further sailing. At noon on August 27 the weather cleared, and they approached Dealey Island, where the huge cairn, topped by three barrels on a post, could be seen for miles at sea. The party went ashore and examined the large cache left by Captain Kellett of the H. M. S. *Resolute* in 1852-53. The walls of the cache were still standing, but there was no roof and most of the contents had been destroyed by the weather and marauding bears. The skeletons of two bears found nearby suggested that they might have been poisoned by consuming some of the spoiled food. Some of the barrels contained clothing, sea boots, flour, chocolate, peas, beans, and tea; all were in a soggy, rotten condition. Some of the iron cans and tanks contained hardtack and canned meats and vegetables, but most of them had been broken into and the contents had spoiled. On the beach close by the men found two broken rifles and a case of ammunition left by Captain Bernier in 1909.

They left Dealey Island on the morning of August 28, and traveled along the low coast to Winter Harbor, about 30 miles to the southwest. Winter Harbor was chosen by Captain Bernier as the winter quarters for his Canadian Government Expedition of 1908-09, and was visited again by him in 1910. The storehouse built by Bernier in 1910 was still in fair condition, although almost empty, and from a rafter hung a bottle containing the record left by Inspector Joy who had last patrolled there in 1929. Numerous tracks of musk oxen, caribou, and wolves were noted around the harbor, but only one old bull musk ox was seen.

After depositing a record at Parry Rock, Larsen and his crew left Winter Harbor on August 30 and had a clear run 30 miles to the south before meeting heavy ice. Due to mist and rain, they moored to a large floe to await visibility and replenished their fresh-water tanks from pools on the ice. Early the following morning they began working their way through the heaviest ice yet encountered, as it pushed eastward from the Arctic Ocean through M'Clure Strait. Several times heavy fog, which obscured leads, prevented progress, and they were gripped by the general counterclockwise revolving motion of the churning, growling ice. Soundings of 50 and 93

fathoms were obtained during the crossing of the strait. They drifted throughout September 1, but toward evening of September 2, after they had worked forward again, the fog lifted and a cape loomed ahead. Larsen did not know which coast of Prince of Wales Strait the cape marked, but decided to turn eastward. The cape proved to be Peel Point, and he soon realized that he was in Richard Collinson Inlet. Since there was much ice in the inlet and more pouring in behind the boat, Larsen did not consider it wise to explore the inlet to its head, and so turned around and retraced his course to Peel Point.

The *St. Roch* entered Prince of Wales Strait on September 3 in bright, clear weather. No ice blocked the passage and good time was made to the southward. Holman Island was reached in midafternoon of September 4, and the exciting news that the vessel had come through the Northwest Passage was given to the amazed Hudson's Bay Co. manager. Although many explorers had spent years in unsuccessfully trying to work through the eastward-moving ice, it had taken Larsen and the *St. Roch* only 18 days from the time they entered Lancaster Sound until they were at Holman Island in the western Arctic.

Larsen received instructions from Ottawa to proceed outside to Vancouver and to complete the coast-to-coast voyage if he could. After he left Holman Island on September 5, heavy ice gave difficulty all across Amundsen Gulf and forced the *St. Roch* to proceed slowly close to the shallow shore of the Canadian mainland west of Cape Parry. On September 8 she was freed of the ice off the harbor at Port Brabant, but ran aground trying to enter it in the dark. Larsen backed her off and was able to get in just in time to ride out the worst storm ever known at this place. Two days later, when the storm abated, the entrance to the harbor was completely changed and Larsen erected new markers. The ice was packed solidly in Mackenzie Bay by the northerly hurricane, and it appeared that the *St. Roch* would have to winter at Port Brabant. On September 17, however, Larsen decided to attempt the crossing, and, after making slow progress through the heaviest ice seen during the voyage, successfully reached Herschel Island. The Eskimo family and dogs from Pond Inlet were left here, along with a large share of the *St. Roch's* coal and other supplies.

The history-making "Mounties" left Herschel Island on September 21, as the harbor was beginning to freeze over, and met more heavy ice and fog along the Alaskan coast. With their goal so close, the cruel Arctic weather was teasing them by making their progress more and more difficult, but the *St. Roch* and her determined crew were not to be denied this time, and their experienced captain countered every aimless movement of the ice. The last of the polar pack was left behind near Wainwright Inlet, Alaska, and the remainder of the voyage

became merely a matter of reaching port. Stops were made at King Island in Bering Sea and Akutan Harbor in the Aleutians.

After they left the Aleutian port on October 4, a violent 2-day storm and heavy swells on the North Pacific provided but a fitting finish to an exciting historic voyage. Toward evening on October 16, the *St. Roch* came into Vancouver Harbor with all flags flying and a large white banner proclaiming the successful trip through the Northwest Passage. Three hundred and sixty-eight years after Martin Frobisher first attempted to enter the Arctic, seeking a northern route, the R. C. M. P. schooner *St. Roch* became the first ship to complete the Passage in a single year from east to west, with a total elapsed time of 86 days. As Captain Larsen expressed it:

We were lucky and had the breaks. No one can predict ice or navigation conditions in the Arctic. What we accomplished this year might be repeated the next, or it might be many years. Much would depend upon the type of vessel used, and the ice conditions of that particular year. Our voyage showed that the Northwest Passage can be traversed in a single year, but does not prove that this could be accomplished every year.



1. R. C. M. POLICE SCHOONER "ST. ROCH" LEAVING THE HARBOR, HALIFAX, JULY 1944.



2. CAPTAIN AND CREW OF THE "ST. ROCH" AT THE END OF THE FIRST HISTORIC VOYAGE, 1940-42.

Left to right: Const. W. J. Parry, cook; Const. P. G. Hunt, deckhand; Const. E. C. Hadley, wireless operator; Staff Sgt. H. A. Larsen, master; Const. F. S. Farrar, mate; Const. J. W. Doyle, deckhand; Corp. M. F. Foster, engineer; Const. G. W. Peters, 2d engineer.



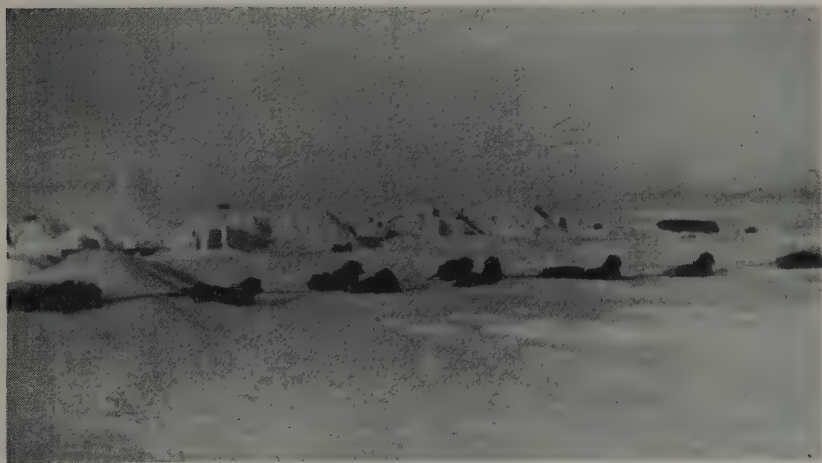
1. "ST. ROCH" FROZEN IN AND COVERED OVER IN WINTER QUARTERS.



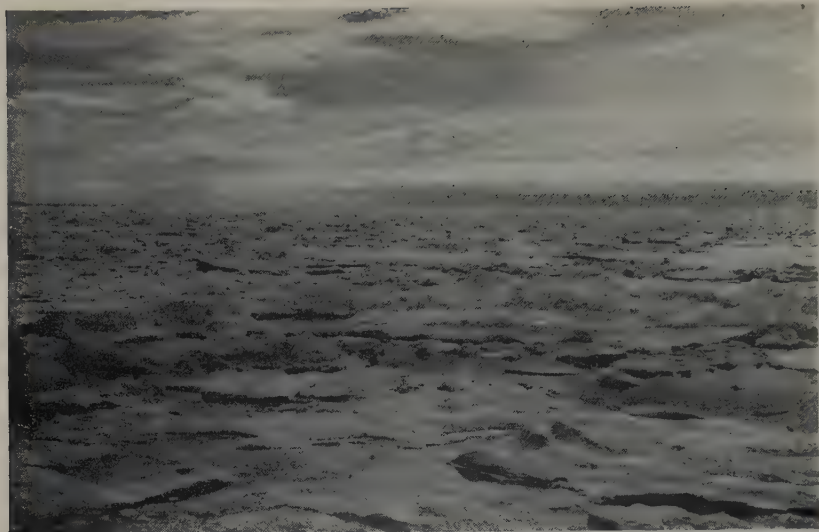
2. LOADING A BASKET-SLED FOR WINTER PATROL TO ESKIMO CAMPS.



1. CONSTABLE PETERS AND ESKIMO GUIDE ENCAMPED ON PRINCE OF WALES STRAIT.



2. SNOW HOUSES IN ESKIMO WINTER CAMP.



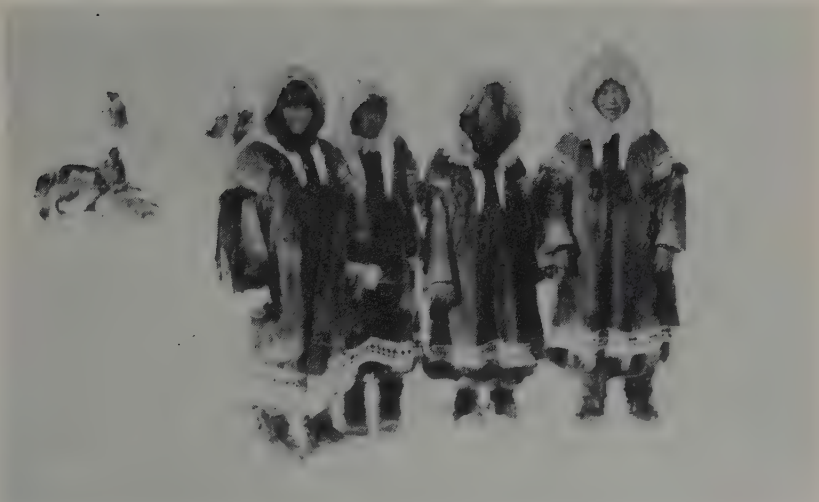
1. HEAVY ICE FLOES PACKED SOLIDLY.



2. "ST. ROCH" STUCK IN ICE OFF BOOTHIA PENINSULA.



1. NATIVES FROM THOM BAY, BOOTHIA PENINSULA, IN WORKADAY CLOTHES



2. NATIVE WOMEN OF BATHURST INLET IN HOLIDAY ATTIRE.



1. STAFF SGT. H. A. LARSEN ON THE TRAIL, VISITING
ESKIMO CAMPS.



2. "ST. ROCH" IN DRYDOCK AT HALIFAX, N. S.
Her wooden hull is undamaged despite 2 years in the ice. Note the
steel plates on the prow.



1. THE TWISTING INLET AT LAKE HARBOR.

"St. Roch" called here in 1943



2 PICTURESQUE PANGNIRTUNG FIORD, THE LAST STOP OF "ST. ROCH" ON HER 1943 PATROL.

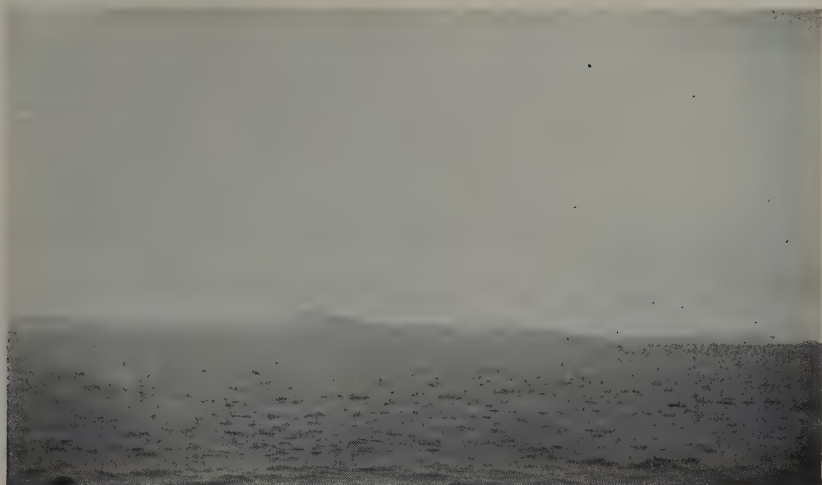


1. CAPTAIN AND CREW OF "ST. ROCH" BEFORE THE RECORD-MAKING 1944 VOYAGE.

Front row, left to right: Const. James Diplock, Huntsville, Ont.; Corp. G. W. Peters, Winnipeg, Man. Corp. P. C. Hunt, Victoria, B. C.; R. Johnsen, Vancouver, B. C.; Staff Sgt. H. A. Larsen, Victoria, B. C. Back row, left to right: Const. M. G. Owens, Winnipeg, Man.; G. Dickens, Chatham, N. B.; Frank Mathews, Fort Abass, Nfld.; Wm. Cashin, Dartmouth, N. S.; Ollie Andreasen, Victoria Landing. Peters, Hunt, and Larsen made the first trip, 1940-42.



2. PASSING GLACIERS AND ICECAP ALONG BAFFIN ISLAND COAST OF NAVY BOARD INLET



1. CAPE BOUNTY, MELVILLE ISLAND, ON THE 110TH MERIDIAN.
The British Admiralty offered a reward of £5,000 for the first passing of this point.



2. APPROACHING BEECHEY ISLAND.
Historic Erebus Bay to right behind cliff



1. THE CAIRN AND RUINS AT BEECHEY ISLAND ARE ON THE FORELAND TO THE LEFT BELOW THE CLIFF.



2. CORPORAL PETERS, CONSTABLE MCKENZIE, AND CONSTABLE ANDREASEN
STANDING BESIDE FRANKLIN MEMORIAL TABLET ON BEECHEY ISLAND.



1. LARGE CACHE BUILT BY CAPTAIN KELLETT, 1852, TO HOLD SUPPLIES FOR FUTURE EXPEDITIONS.

Note empty tins left by Kellett's expedition.



2. INSIDE OF KELLETT'S CACHE ON DEALEY ISLAND.

Most of contents now destroyed.



ARRIVAL OF THE "ST ROCH" IN VANCOUVER, B. C., AFTER SUCCESSFULLY TRAV-
ERSING THE NORTHWEST PASSAGE FOR THE FIRST TIME IN A SINGLE YEAR.

THE NEW ENGLAND HURRICANE OF SEPTEMBER 1944¹

By CHARLES F. BROOKS and CONRAD CHAPMAN

*Harvard University
Blue Hill Meteorological Observatory, Milton, Mass.*

A great hurricane in the Puerto Rico-Bahamas region is always a menace to New England. If the storm, instead of striking inland or recurving out to sea in the usual way, heads up the Atlantic Coast with increasing northward velocity, the danger becomes imminent. For this to occur, there must be a broad northward current at heights of 2 to 5 miles and an ample supply of warm, moist air to maintain its energy.

The 1944 storm developed under general atmospheric conditions not unlike those prevailing at the time of the 1938 hurricane.² At 4 p. m. (E. W. T.) on September 8 the presence of a tropical disturbance was announced from San Juan, P. R., and on the 9th a badly shaken reconnaissance plane found that it was an intense storm at about 21° N., 60° W., which later reconnaissance proved to be a fully developed hurricane moving west-northwestward.³ From September 9 to 11, while the storm was slowly approaching the Carolinas (some 1,000 miles distant), two prongs of tropical-maritime air were pushing northward, one from the central Gulf coast, carrying a small hurricane with it, the other from the Bahamas, forming a low over Hatteras. Caught between these, a wedge of high pressure over the Appalachians declined during the 12th and 13th. Meantime, the anticyclone that had covered the eastern United States on the 9th joined the Bermuda high and thus built a pressure ridge,⁴ favoring on its west side the northward movement over the coastal waters of large volumes of tropical air.

¹ Reprinted by permission, with revisions and additions, from the *Geographical Review*, vol. 35, January 1945.

² Brooks, C. F., *Hurricanes into New England*, *Geogr. Rev.*, vol. 29, pp. 119-127, 1939. (Reprinted, with revisions, in *Ann. Rep. Smithsonian Inst. for 1939*, pp. 241-251, 1940.)

³ [Summer, H. C.] The North Atlantic hurricane of September 8-16, 1944, on back of Daily Weather Map, Oct. 31, 1944, U. S. Weather Bureau, Washington, and with addition of four photographs of damage at Atlantic City and a chart of the tracks of the hurricanes of 1815 and 1821, in *Month. Weather Rev.*, vol. 72, pp. 187-189, September 1944. (Small-scale maps of the isobars of the storm were published for 11:30 p. m. September 13, and 5:30 and 11:30 a. m. (E. W. T.) September 14 on the back of the Daily Weather Map, October 6, 1945. For reference to map of 6:30 p. m. September 14, see footnote 8, below.) This is an extensive discussion with track map and tables, including comparison with the 1938 hurricane.

⁴ A similar pressure ridge in 1938 is shown in figure 1 of the article cited in footnote 2.

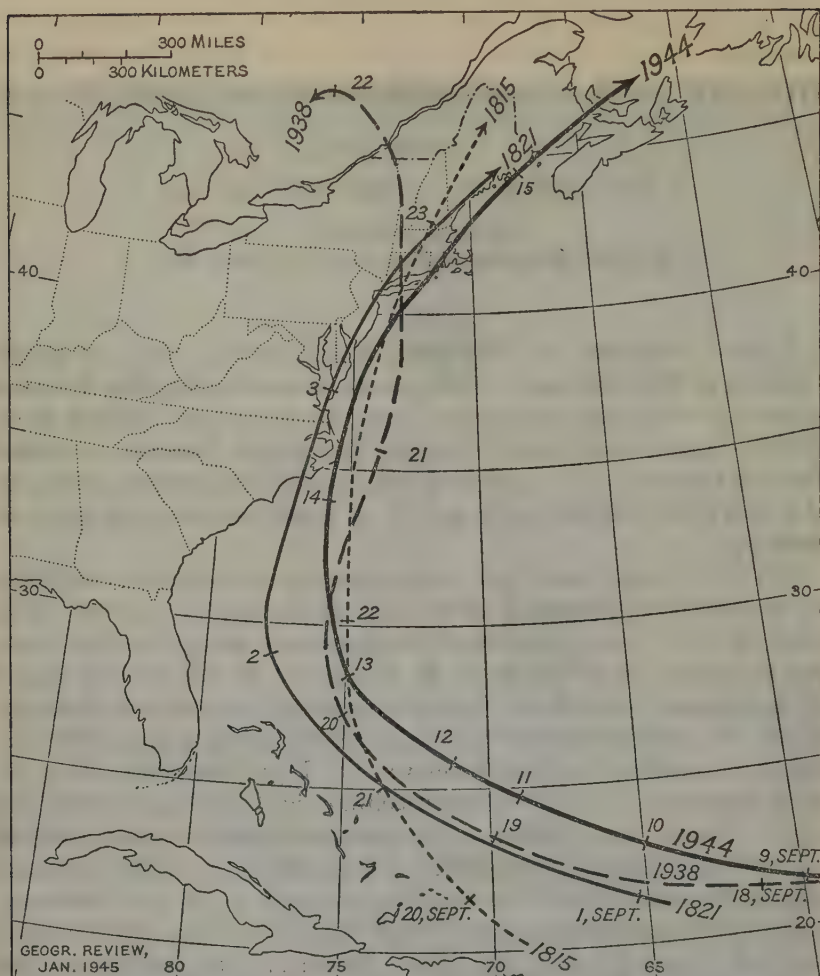


FIGURE 1.—Tracks of the hurricanes of 1815, 1821, 1938, and 1944 (origins not shown). Date positions are those at 7 a.m. The tracks of the storms of 1938 and 1944 differ a little from those heretofore published, for the following reasons: With regard to that for 1938, Mr. I. R. Tannehill, the chief hurricane expert of the Weather Bureau, and author of "Hurricanes: Their Nature and History" (5th ed., Princeton, 1944), wrote (personal communication, late 1944): "It seems to me that it would be better to place the center of the hurricane at about the 74th meridian as it passed Hatteras. Pierce's maps (The meteorological history of the New England hurricane of September 21, 1938, Month. Weather Rev., vol. 67, pp. 237-285, figs. 12 and 18, August 1939) would indicate that at 4 p. m. on September 21, the radius of the area covered by the 29.60 isobar had increased considerably, whereas the radius of the area covered by the 29.30 isobar would have diminished somewhat, judging by reports to the westward. It seems more reasonable to assume both had increased in this interval, I think you are right that some of our charts show the center a little too far to the westward as it passed Hatteras, but it seems to me that a position about midway between the two (near 74° W.) would

On the 13th, at 4:30 a. m. (E. W. T.), the storm was centered near latitude 27.8° N., longitude 74° to 75° W., about 380 miles off Florida, moving northwest at 10 to 12 miles an hour (fig. 1). At 2:30 a. m. on the 14th it had just passed the point of recurvature and had begun, though still slowly (20 miles per hour), its march northward with the upper current. Seven hours later, now advancing more rapidly (about 30 miles per hour), its center passed close east of Hatteras, where the barometer stood at 27.97 inches (947.2 millibars) and gusts were estimated to reach 140 to 150 miles an hour.

THE HURRICANE IN FULL FORCE AT CAPE HATTERAS, ITS FIRST LANDFALL

We are indebted to Reverend F. B. Dinwiddie for an exceptionally complete account of the meteorological features of this great hurricane as it approached, passed over, and receded from Cape Hatteras. Reverend Dinwiddie deserves great credit for making such a record under the conditions of a storm of such exceptional violence. In view of the fact that the storm reached its first land at Cape Hatteras and was still very much in possession of its full tropical characteristics, these observations seem worth presenting in some detail. They reveal unexpected complexities in the great whirl.

The storm's approach was observed from Nag's Head, on the outer barrier beach, but its full fury was noted from a less hazardous location at Wanchese, 8 miles to the southwest. The advance edge of the cirriform overflow from the storm was already in sight at 8 a. m. the 13th, while the center was still 500 miles to the south; and by noon the sky was half covered with cirrostratus which showed a halo from 12 to 5 p. m., when altostratus became dominant.

Heavy cumulus swelled up here and there during the morning while the sun still shone. A peculiar squall, estimated at 40 miles an hour, came very suddenly at noon, with no lower clouds in the vicinity and no change from the steady south-southeast wind direction. Reverend Dinwiddie rather plausibly wonders if it could have been the result of penetration from the upper air stream in advance of the storm,

be more nearly correct." With regard to the track of the 1944 storm, observations at Avon, N. C., presented by Rev. F. B. Dinwiddie, where the wind, even on this outermost barrier beach, 10 miles north of Cape Hatteras, went from easterly to westerly via north, as the center passed, indicated that the center was to the east, instead of to the west (cf. Sumner, loc. cit. footnote 3, ch. 1, and Wood, F. B., A flight into the September 1944 hurricane off Cape Henry, Va., Bull. Amer. Meteorol. Soc., vol. 26, p. 154, fig. 2, May 1945). The center must have been close, however, perhaps only 5 or 10 miles away, because the wind became gentle for $1\frac{1}{2}$ hours. Farther north, the track published by Sumner and Wood is some 20 miles too far west where it crosses southeastern New England.

augmented by storm overflow the sudden descent of which was induced by convection. The wind had been increasing in velocity during the morning, from 10 to 20 miles an hour between 8 and 11, apparently owing to the increasing involvement of the wind higher and higher up as the depth of the convective overturning increased. With cloudiness cutting off most of the sun after noon, however, the wind again fell back to its 10 miles an hour morning value by 3 p. m.

TABLE 1.—*Summary of personal journal of F. B. Dinwiddie during hurricane at Wanchese,¹ N. C., September 14, 1944*

Time (E. W. T.)	Pressure (sea level) (inches)	Wind		Rain and clouds		
		Direction	Estimated gust velocity (m. p. h.)			
Hurricane period during approach of center, 115 minutes						
a. m.						
8:15	28.94	NE x E	70	Heavy rain.		
8:35	28.83					
8:40	28.80					
9:00	28.65					
9:20	29.53	Fastest drop { ENE	85 gusts	Very heavy rain.		
9:30	28.43		90			
9:40	28.37		95			
9:54	28.26		100			
10:05	28.17		100-120	First pronounced lulls in wind.		
Passing of the center, 75 minutes						
10:10	28.12			Rain slackening.		
10:20	28.03	Shifting to N	80			
10:30	28.00		70	Moderate rain, sky bright		
10:35	28.01	Pressure around 28.00 in. for 35-40 minutes.		Slack rain, sky dark	Intermittent bright spots for 50 minutes but no clear sky or high clouds visible. 10/10 stratus throughout.	
10:40	28.00		N	30-40		No rain
10:45	28.01		N	20-30		No rain
10:50	28.00		N x W	60		No rain
10:57	27.99			60		No rain
10:59	28.02			No rain		
11:05	28.01	NNW	85	No rain		
11:10	28.05		90	Moderate rain		
11:20	28.09		80-100	Rain squalls, intermittent bright spots.		
Hurricane period after passage of center, 105 minutes						
11:30	28.15	NW	120	Continuous heavy rain, dark sky.		
11:50	28.33	NW	130			
11:53	28.40	Fastest rise {				
12:00	28.50		110-120			
p. m.						
12:10	28.59		120			
12:27	28.70	NW x W	130			
12:50	28.90	WNW	140	Very heavy rain		
1:00	28.98	WNW	140-150	Worst wind; storm 35 minutes.		
1:02	28.96 ²			No slackening of wind, rain		
				Final phase of diminishing wind.		
1:12	29.01	WNW	70	Light rain; scuds lifting; very abrupt decrease of wind and rain.		
1:30	29.10	WNW	60	First blue sky in southwest; rain stopped		
1:38	29.18		55			
3:00		W x N	45	1:30-2:00 sprays from breakers 150 ft. high.		
4:25	29.48	W	30	Edge of Cs. bank in zenith.		
6:40	29.58			3/10 cloudy; bank receding in N. x E.		
9:15	29.68	W	10	Clear.		

¹ Wanchese is on the west shore of an island in Pamlico Sound, about 40 miles north of Cape Hatteras and 6 miles from the coast of the open ocean.

² Retrogression of barometer.

Though the sky became completely covered with altostratus before sunset, there were breaks during the evening, and, indeed, mostly clear sky overhead at midnight, an hour before light showers began. Distant lightning was visible at 10 p. m. The wind had slowly swung to southeast at 9 p. m., but by 10:30 had gone to east, as the pressure, steady all day (around 29.75 inches, 1,007 millibars), began its unbroken descent. By 1 a. m. the wind had gone to east-northeast and increased to 20 miles an hour.

At 5 a. m., when the center was within 150 miles, the barometer began to plunge (from 29.57 inches, 1,001 millibars) and the wind began to reach gale force and increase rapidly (estimated average, 30 miles an hour at 5). Steady rain commenced before 6. Details of the next 13 hours are presented in table 1.

OBSERVER'S NOTES WITH REGARD TO THE TABLE

Observation of wind direction not guaranteed within 10° or 12° because observed from unfamiliar location in clearing surrounded by woods. The observer is certain, however, that throughout the entire period of strong winds, the wind direction failed by as much as 30° or more of achieving a 180° shift such as might be expected in a storm of this type.

Wind velocities given were estimated from the stronger intervals varying from several seconds to more than a minute, so that they would represent a combination of values from 5-minute averages up to fastest miles and gusts, depending on the length of each blast of wind. We should think our 5-minute maximum between 12:50 and 1 p. m. was not less than 90 miles an hour, for the wind during the climactic period seemed sustained at the extreme level with comparatively little fluctuation and no respite, until the amazingly sudden relief came at 1:10 p. m., when the 70-mile wind seemed like a breeze by contrast.

OBSERVER'S INTERPRETATIONS

I was especially impressed with the evidence suggesting an abnormally large central area of no rain and reduced wind. At Avon, N. C. [10 miles north of Cape Hatteras and 10 miles nearer the center than the Weather Bureau Station, Hatteras], the rain stopped for about 1½ hours as the center passed. The wind dropped to a gentle breeze. It shifted to West by way of North, so the track of lowest pressure passed east of this point. At Wanchese [15 miles farther from the center] the rain stopped for about half an hour while we were inside the 28.00-inch [948-millibar] isobar. This would suggest a vast eye perhaps 50 miles or more in diameter whose center could have been east of the coast at all times. Our wind also diminished during this period, to a minimum of about 25 miles an hour.

The winds of hurricane force were limited to the area inside the 29.00 [-inch, or 982-millibar] isobar and outside the 28.00 [-inch, or 948-millibar] isobar. If my data are anywhere near correct . . . the storm did not exceed a speed of 30 miles an hour along its track until it was past the latitude of Cape Henry, Va. We estimated our wind gusts reached 140 miles an hour during the latter half of the storm, which was considerably more violent than the first part, when the strongest wind seemed to be about 100 miles an hour. [The isobars were more or less egg-shaped, and farther apart (less gradient, less wind) ahead of the storm than to the side or rear.]

Our greatest hour's pressure fall was 0.5 inch [17 millibars], and the greatest hour's rise was 0.57 inch [19 millibars]. During one 10-minute interval the pressure rose 0.17 inch [6 millibars]. The steepest gradient I could measure was that extending from Elizabeth City, N. C., to the [margin of the eye at the] storm center at 11:35 a. m., a pressure difference of 0.90 inch [30 millibars] in 38 miles, which on a map drawn for 3-millibar interval would place the isobars less than 4 miles apart. [Apparently within the 28.90-inch (979-millibar) isobar the pressure gradient decreased little if any outward from the center. Consequently, the maximum wind occurred at about the time of passage of the 979-millibar isobar, which was some time after the passage of the center for the stations practically on the track (Hatteras, 1 hour 40 minutes; Wanchese, 2 hours), but virtually at the time the center was nearest for stations at or beyond the 60-mile distance of the 979-millibar isobar from the center (Elizabeth City, N. C., and Norfolk, Va., 5 minutes difference; Cape Henry, 12 minutes).]

THE STORM NORTH OF HATTERAS

The transformation from a slowly moving completely tropical storm to a rapidly moving cyclone with middle-latitude features was now in progress. Cooler, drier air from the land curving around the rear tended to make the pressure rise more rapidly behind, while the warm sea air flowing in ahead made it fall more rapidly in front. Cool air on the northwest also had increased the northwestward pressure slope aloft, thereby accelerating the general current that later carried the storm; and energy from the tendency of the colder, denser air to underrun the warmer, lighter air mass offset in part the decreasing receipt of tropical vapor as the storm entered cooler latitudes.

The combined effect caused a still more rapid increase in the speed and a change of direction of the cyclone, at first toward the north-northeast, parallel to the coast to northern New Jersey, then toward the northeast, across Long Island east of Suffolk Airport. The center traveled the 400 miles from Hatteras to Long Island in 11 hours. The barometer at Suffolk fell to 28.42 inches, and gusts reached 100 miles an hour.

At Bridgehamton, about 18 miles east of Suffolk Airport, the center also passed on the east. Ernest S. Clowes writes:⁵

There was a distinct "calm center" from about 10 to 10:30 p. m., E. W. T. The lowest barometer occurred soon after 10, and for about half an hour the wind was, I'd say, around 10 to 15 m. p. h., with the sky mostly clear and starlit though with occasional smart showers, very brief. The wind was variable but mostly NE. to N. At 10:45 I estimated the wind as 65 m. p. h. from NW. The rainfall for the storm, 5 to 11 p. m., was 2.78 in.

The center continued moving northeastward, at 35 to 40 miles an hour, passing between Fishers Island and Block Island, across Rhode Island (between Westerly and Point Judith, East Providence), southeastern Massachusetts (East Wareham, Taunton, Brockton, South

⁵ Personal communication.

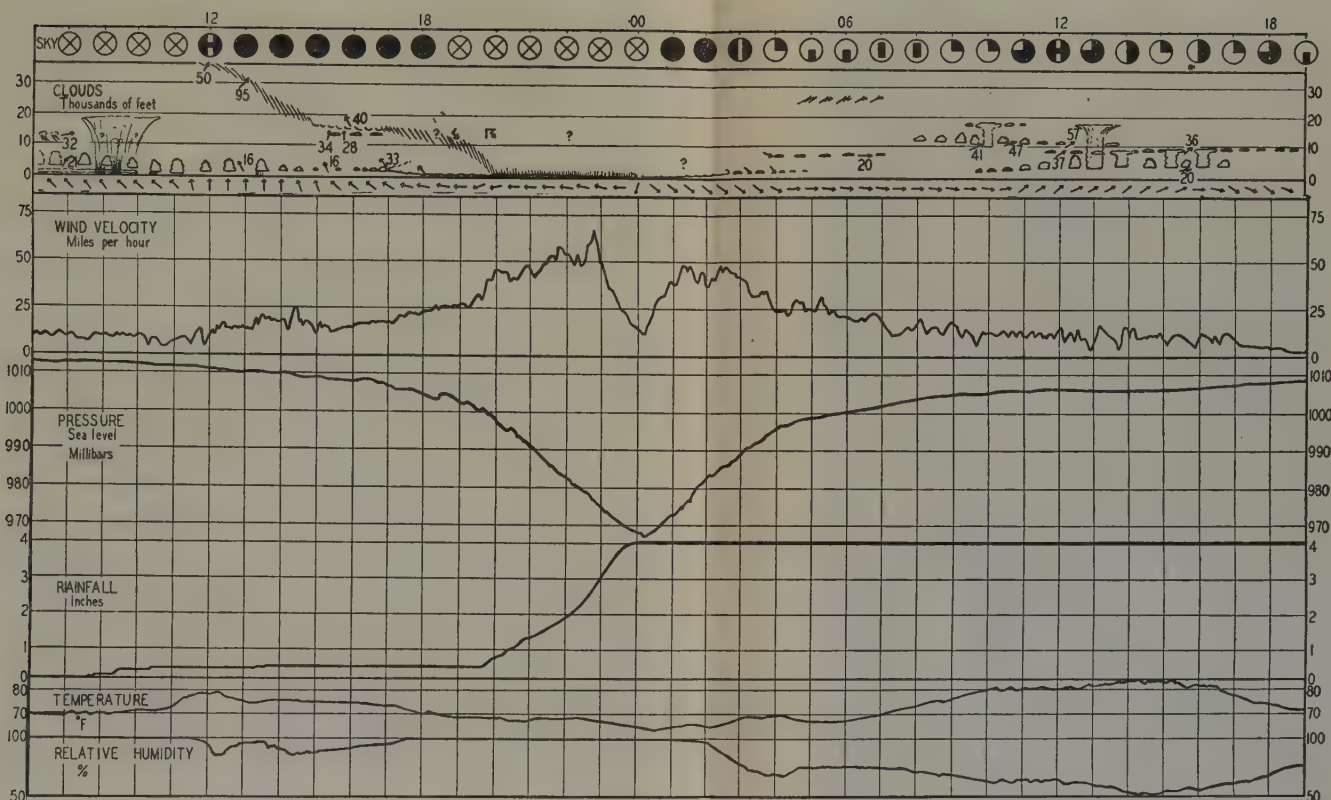


FIGURE 2. (by John H. Conover).—The hurricane of September 14–15, 1944, as observed and recorded at the Blue Hill Meteorological Observatory, Milton, Mass. (635 feet above sea level). The track of the center of lowest pressure passed about 10 miles south-east of Blue Hill, and the observatory was within the central zone of lighter wind for more than an hour.

Symbols used on United States weather maps are employed for the hourly cloudiness, the circle with a cross in it representing sky obscured by cloud so low as to envelop top of Blue Hill, and the others graphically depicting roughly the amount of sky cover. The cross-sectional cloud diagram is based on observed forms, heights obtained by range finder, and directions and velocities by nephoscope. The arrows indicate direction of movement as if the top of the chart were north. The same applies to the arrows for half-hourly wind direction, immediately below the cloud diagram. A zigzag arrow represents lightning, and a symbol somewhat like an "R" with such an arrow included represents a thunderstorm. The wind velocities are the 5-minute averages by 3-cup anemometer. Pressure is from the record of a mercurial barograph, rainfall from a weighing rain gage, and temperature and humidity from a thermohygrograph, all with open scales.

This hurricane weather diagram for a storm with center passing nearby on the east is to be compared with a similar diagram for a storm (1938) with center passing at some distance on the west. (See Ann. Rep. Smithsonian Inst. for 1939, p. 246, fig. 2.)

Weymouth), Massachusetts Bay, the southeast tip of Maine (Eastport), lower New Brunswick (Pennfield Ridge, Blissville), and Summerside and Charlottetown, Prince Edward Island,⁶ and then across Newfoundland. It finally merged into an extratropical cyclone southeast of Greenland. The "eye" of the storm, with its lull and starlit skies, was seen as the center passed Providence at 12:20 a. m. on the 15th; at South Weymouth at 1:15 a. m. (also at Milton, 10 miles from the track); at Rockport at 2 a. m.; and at 4:30 a. m. as it skirted Portland, where the wind dropped from 30 to 10 miles an hour. The central area of light winds was diffuse and extensive, reaching more than 30 miles to the left of the path of lowest pressure.

Details of the storm, as carefully observed and recorded in detail by open-scale automatic instruments at Blue Hill Meteorological Observatory, are presented in figure 2, to indicate its features after some weakening and stretching as it got into middle latitudes.

FORECASTING THE COURSE

Predicting the course a tropical hurricane will take if it moves into higher latitudes requires constant attention. The factors are not to be fitted into a simple formula. They are, chiefly, surface and upper air pressures, pressure gradients, and related wind fields; temperature and moisture gradients; and, if over land, the roughness of the terrain.⁷ These control the movement of the atmosphere in which the hurricane is carried along and also the storm's supply of energy and frictional drag; they thus determine the speed, direction, and force of the storm.

As early as the 12th the probability that the storm would enter New England was thought to be high. Upper-air observations showed a closed cyclone at 10,000 feet over the Southeastern States; from this, one might have expected the hurricane, after going ashore, to curve back toward the north-northwest or northwest, somewhat as the 1938 storm did. But on the 13th the arrival of colder air in Canada, with its more rapid decrease of pressure upward than in the warmer air, steepened the northward pressure gradient aloft, thereby opening the upper-air cyclone and making the wind at 10,000 feet turn southerly in the Middle Atlantic region and southwest to west-southwest over the North Atlantic States. This indicated that the storm would recurve rather sharply and follow a northeast to east-northeast direction, passing, perhaps, just south of New England. On the morning of the 14th it was evident from the shift of the winds aloft more to the south that the arc of recurvature would

⁶ G. H. Noyes of the Boston office of the U. S. Weather Bureau, to whom the authors are indebted, has compiled a schedule of the position of lowest pressure.

⁷ See Wexler, Raymond, The filling of the New England hurricane of September 1938, *Bull. Amer. Meteorol. Soc.*, vol. 20, pp. 277-281, 1939.

be flatter and that the center of the storm would go ashore over eastern Connecticut or Rhode Island and pass near Boston.

In forecasting, the winds at 10,000 feet were considered fairly definitive, though some weight had to be given the wind at 20,000 feet in view of the great vertical extent of the storm, which, according to Major Wexler's estimate (see fig. 3) reached 48,000 feet. Range-finder measurements on the cirrostratus over Blue Hill, Mass., in advance of the storm indicated some 36,000 feet.

Cloud observations, which at such times are the quickest and easiest way of following rapid changes in the upper and middle winds, were made assiduously all day on the 14th at Blue Hill (see fig. 2) and were reported at frequent intervals to the Boston Weather Bureau. A comparison of these with similar observations made at Blue Hill on September 21, 1938, throws an interesting light on the direction, speed, and other aspects of the 1944 storm. For instance, in 1938 the clouds were mostly from the south at about 60 miles an hour, drifting in the fast general current in which the storm was moving rapidly straight northward. In 1944, at about 1 p. m. on the 14th, cirrostratus and cirrocumulus, with a fine halo, emerged from behind a breaking layer of low clouds. They were from the southwest at close to 100 miles an hour. These were on the advanced edge of the vortex and were traveling much faster than the center at the surface. Four hours later the base of the sheet of ice crystals had fallen to 18,000. At that level, already well within the whirl of the hurricane, the wind was from the south at 37 miles an hour. The observer, a few hundred miles northeast of the surface center, thus measured the directions and speeds of clouds on a cross section of the vortex. This last was probably inclined forward to the northeast and spread out aloft over a vast region.

A DARING FLIGHT INTO THE HURRICANE

A view of the storm from the air as it passed Virginia was undertaken by three intrepid Army Air Forces weather officers, Col. F. B. Wood, Maj. Harry Wexler, and Lt. Frank Record. Their observations of clouds, rain, and vertical currents did not fit into conventional textbook patterns. Colonel Wood describes the flight of the airplane virtually to the center of this terrific storm;⁸ and Major Wexler attempts to coordinate these observations into a reasonable dynamic structure.⁹ The results of his efforts which he worked out in diagrammatic form are reproduced from his article in figure 3. The most

⁸ Wood, F. B., A flight into the September 1944 hurricane off Cape Henry, Va., *Bull. Amer. Meteorol. Soc.*, vol. 26, pp. 153-156, May 1945. Includes weather map for 1830 h. September 14 and a map of the flight.

⁹ Wexler, Harry, The structure of the September 1944 hurricane when off Cape Henry, Va., *Bull. Amer. Meteorol. Soc.*, vol. 26, pp. 156-159, May 1945. Includes generalized map, and a cloud, rain, and circulation cross-sectional diagram.

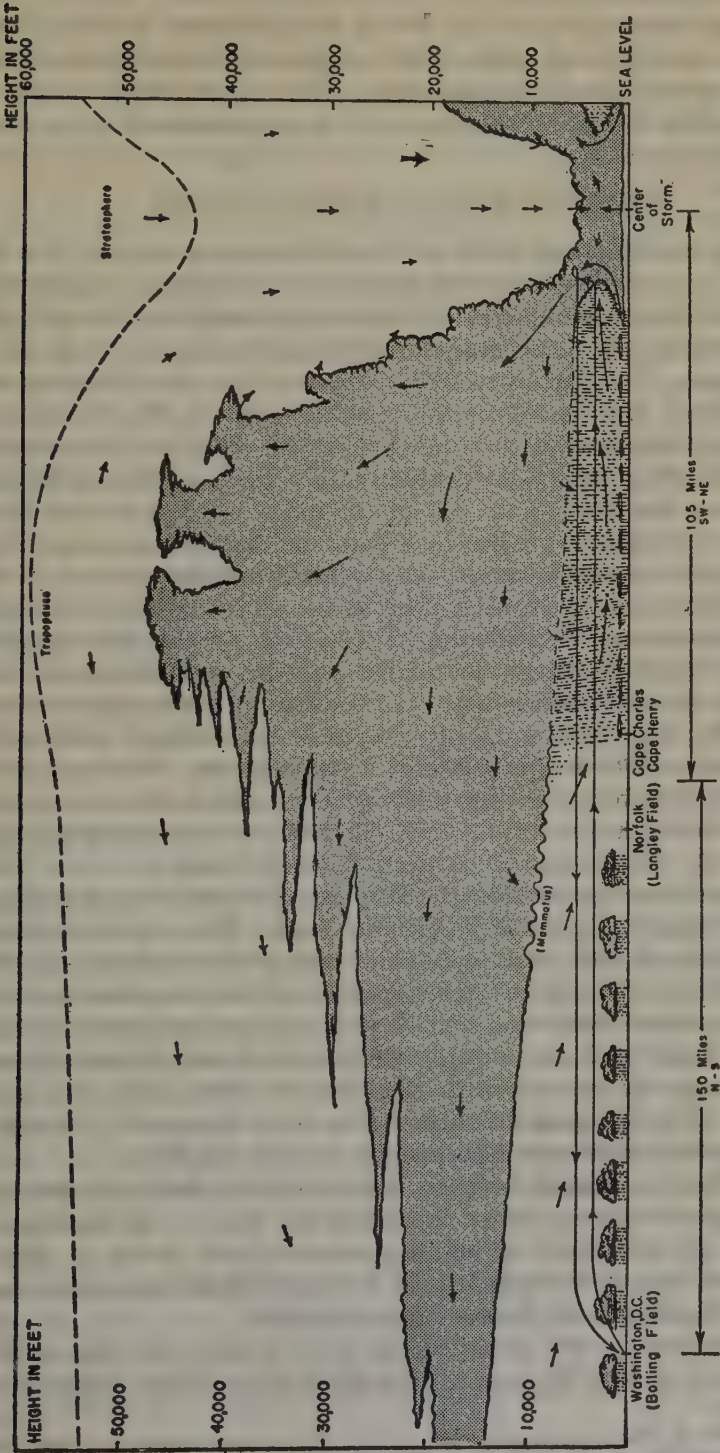


FIGURE 3 (by Maj. Harry Wexler, A. C.).—Radial cross section of the circulation, clouds, and rain in the southwest quadrant of the hurricane of September 14, 1944, as it passed Cape Henry, Va. (Reproduced from Bull. Amer. Meteorol. Soc., vol. 26, p. 158, fig. 4, 1945.)

surprising observation was the strong and persistent descent of air observed at a height of a mile in the southwest quadrant of the storm near the outer limits of the rain area. This was evidently in partial compensation for the terrific ascent of large volumes of air around the central core.

FORCE AND EFFECTS OF THE HURRICANE

During the 14th, peak winds at the surface were generally 75 to 90 miles an hour and showed little evidence of weakening. Variations between different points could not be related to changes in the strength of the storm as a whole, because of differences of exposure and distance from center. The highest wind velocity recorded was 134 miles an hour at 12:20 p. m. on September 14 at Cape Henry, Va. Maximum (5 minutes) wind velocities equaled or exceeded all previous records at Hatteras, Cape Henry, Atlantic City, New York, and Block Island.

However, the wind on the left of the storm when it reached New England was appreciably less than had been expected, as a result of friction over the rough terrain, the greater proportion of land air in the circulation, the cushioning effect of the cooler night air, and the more rapid advance of the center. These effects were slightly reduced by the increase in energy due to the greater contrast between the density of the cooler air over the land and that of the warmer air over the ocean. The wind on the right, however, retained practically its full force, since it came straight in from the sea. The increasing southeast-northwest general pressure gradient added somewhat to the wind on the right of the vortex and offset to a certain extent the tendency of the wind to decrease as the cyclone weakened.

Between its emergence from the Tropics and its arrival in New England the storm lost some of its original force. This was not true of the hurricane of 1938, because then the much greater difference in the temperature on the east and west sides (the land air was much cooler) created potential energy that compensated in large measure for the loss in latent heat,¹⁰ and the storm, being well out to sea, did not lose so much energy by friction with the land en route. The east-west diameter of the storm at the surface (inside the isobar of 1,005 millibars) was 520 miles on the 14th, and 420 miles on the 15th.

A further weakening, between the time when the storm entered New England and that when it reached the Gulf of St. Lawrence, is shown by the record of lowest pressures: 28.34 inches at Block Island and 28.31 at Point Judith, R. I.; and 29.19 at Summerside and 29.18 at Charlottetown, Prince Edward Island.

The tropical air that preceded the storm brought the first of the heavy rains to New England on the night of the 12th. These were

¹⁰ Pierce, C. H., *The meteorological history of the New England hurricane of September 21, 1938*, Month. Weather Rev., vol. 67, pp. 237-285, 1939.

heavier along the south shore of Connecticut, and decreased more or less uniformly northeastward to Maine. They continued, intermittently, through the following 48 hours, extending both northward and northeastward into Canada, much less uniformly, and giving no indication of the future course of the hurricane.

The cyclonic "wringer" produced the usual hurricane rains. But in a rapidly moving whirl the convergence and consequent ascent and resulting rainfall are much the greatest in the left front quadrant, especially when this alone of the whirl is over land, whereas the right or "dangerous" quadrant receives hardly any. For instance, the hurricane rainfall at Hartford, on the left of the track, was 4.3 inches, whereas at Nantucket, about the same distance to the right, it was 0.11 inch. Providence, nearer the center, but still to the left, got 4.7 inches, of which $3\frac{1}{4}$ came in 2 hours, with a southeast wind averaging 34 miles an hour. In the 1938 hurricane also, the precipitation on the left of the track was very heavy, in marked contrast with negligible rainfall on the right.

Hurricane tides, which are a great danger on the coast and some miles up from the mouths of rivers, were not very serious in 1944, because the arrival of the storm on the south coast almost coincided with low tide. Increases in height that can be attributed directly to the hurricane are, approximately: Boston, 2.5 feet; Woods Hole, 7 feet; Newport, 8 feet; Providence, 9 feet; New London, 6 feet.¹¹ Maximum tides (normal high tide plus hurricane tide) during the 1938 hurricane were: Sandy Hook, 8.2 feet; along the Connecticut coast and shore of Narragansett and Buzzards Bays, 12 to 25 feet; Point Judith, 18 feet; Providence, 17.6 feet; Fairhaven, estimated 25 feet; Fall River, estimated 18 feet.¹²

Much more damage was done by the surf than by the wind, because of the reach of nearly a thousand miles from the position of the storm off Florida to the Long Island and southern New England coast. Thanks to the long advance warning of the Weather Bureau, small craft and most other shipping had had time to seek shelter. Not all vessels, however, could do so. The Vineyard Sound lightship foundered at her post, with a loss of 12 lives. She was later located in 11 fathoms of water, the mooring chains intact, at a considerable distance from her Cuttyhunk station. Evidence of the force of the surf is found in the diver's report: masts and funnel were sheared off flush with the deck.

The American Red Cross estimates the havoc wrought by the 1944 storm between North Carolina and Massachusetts as follows: 46 persons killed and 338 injured, 921 houses destroyed and 24,168

¹¹ Courtesy of the U. S. Coast and Geodetic Survey.

¹² Tannehill, I. R., *Hurricanes: Their nature and history*, 5th ed., p. 43, Princeton, 1944.

damaged, 1,641 other buildings destroyed and 16,832 damaged, 131 boats destroyed and 635 damaged.¹³ In addition, heavy marine casualties directly related to intensified patrol and other war exigencies amounted to 344 men and 5 vessels.

From other sources¹⁴ the property damage for the 1944 storm may be placed at \$100,000,000, as against \$300,000,000 for the 1938 hurricane.

One or two examples of damage may be noted. At Nantucket the Coast Guard Station was washed away. At Newport, with a maximum wind velocity of 84 miles an hour at nearby Quonset, more trees were destroyed than in 1938. The 1944 storm passed 50 to 100 miles nearer the shores of North Carolina, Virginia, Delaware, and New Jersey than the 1938 one. That is why those coasts suffered so much more damage this time.¹⁵

But for the experience gained in the 1938 hurricane and the lessons it taught, the 1944 storm would have cost more lives and created far more havoc.

A hurricane observing and warning service has been set up in the North Atlantic States. More attention has been paid to the direction and velocity of the middle and upper levels of the air stream in which a hurricane may be traveling. Cloud movements as indicators have been more carefully studied at weather stations in recent years. An important development in this connection is the tracing of balloons by radio—both by radar and by radio direction finding. This method, known as "rawins," made possible the determination of all winds aloft in the vicinity of the several stations possessing the necessary equipment. This method is invaluable ahead of the storm, where low clouds usually obscure the higher ones. A radiometeorograph network for deep atmospheric soundings has been extended. A special teletype system has been installed, and other necessary improvements have been made.

The Weather Bureau is to be congratulated on the accuracy of its forecasts and on the wide dissemination of timely warnings by radio and other means while the danger lasted, thereby saving many lives¹⁶ and much property.

¹³ Courtesy of North Atlantic Area, American Red Cross, New York. According to the American Red Cross, quoted by Sumner, *op. cit.* (footnote 3), the 1938 storm killed 494 and injured 708. It destroyed 936 houses and damaged 8,019, and destroyed 3,564 other buildings and damaged 7,120; 2,605 boats were destroyed and 3,369 damaged.

¹⁴ Day, R. L., in an article on the hurricane published in the *Franklin Journal*, Farmington, Maine, October 10, 1944; and Sumner, H. C., *op. cit.*

¹⁵ The great destructiveness of this storm is vividly revealed in "Hurricane," a picture booklet of 52 pages published by The Standard-Times, New Bedford, and The Cape Cod Standard-Times, Hyannis, Mass., 1944.

¹⁶ One such survivor, Dr. Victor Conrad, whose scientific curiosity was nearly his undoing, has described the deep, booming sounds of the black hurricane night and the effects of physical features in varying the destructiveness of sea and wind at Hyannis, Mass., in "Some Remarks upon the Destructive Effects of the Hurricane, September 14-15, 1944, observed at Hyannis, Cape Cod, Massachusetts," *Trans. Amer. Geophys. Union*, vol. 26, No. 2, pp. 217-219, October 1945.

CONSERVING ENDANGERED WILDLIFE SPECIES¹

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[With 13 plates]

Most of us are familiar with such expressions as "gone like the dodo," or "as extinct as the dodo." The dodo was a huge, grotesque, aberrant member of the pigeon tribe, reported to have first been discovered in 1497 by Vasco da Gama on the island of Mauritius. For many years it carried the appropriate scientific name *Didus ineptus*, for of all birds it was most inept to meet the competition with humans that was to confront it. About the size of a swan, ungainly, pot-bellied, wings so aborted that it lost the power of flight, ground-nesting and laying only a single egg, and unsuspicious to the point of stupidity, it fell an easy prey to the crews of Dutch ships that visited Mauritius during the first quarter of the seventeenth century and to the Dutch who settled the island in 1644. By 1693 the dodo was extinct. Likewise, a closely related bird species, the solitaire of Rodriguez Island, became extinct about the middle of the eighteenth century. These are striking examples of what has happened to many species in the history of the world fauna, sometimes, as in these cases, with known cause, but more often with cause unknown. It is regrettable to have to record the passing of any wildlife race, even though the form may be of only esthetic or educational value. Once a type becomes extinct, it never reappears. It behooves us to care for what we have.

POSSIBLE CAUSES OF WILDLIFE REDUCTION AND EXTINCTION

Many factors have probably been involved in the extinction of animals. In the geologic past before the advent of man we might theorize on the causes of such extinctions not attributable to man.

¹ Based on a lecture delivered on January 15, 1941, to the class in wildlife conservation of the Graduate School of the U. S. Department of Agriculture. Reprinted by permission, with additional illustrations, from Transactions of the Wisconsin Academy of Sciences, Arts, and Letters, vol. 35, 1943. The photographs are from the files of the U. S. Fish and Wildlife Service, unless otherwise indicated in the legend. All maps were prepared by Mrs. Kathryn Tabb, of Biological Surveys, Fish and Wildlife Service.

Since man's appearance on the scene in recent times, with one or two possible exceptions all cases of wildlife extinction can be lodged in his own hands. Factors other than man's behavior may have resulted in heavy local, or often perhaps widespread, losses in wildlife, but have rarely endangered the existence of the species. It is difficult in most cases to determine the exact cause or causes of an extinction. Often it appears that it may be one factor, or again it may be several. Extinction in every case was probably brought about at first by gradual depletion of the population and through local extirpation. When the population becomes reduced to a danger point, extinction may come with unexpected rapidity. Dislike the assertion as we may, in recent times the human species has been the prime factor in the extermination of other species.

Man.—Man has aided in faunal destruction by the injudicious commercialized use of wildlife. In order to realize this we have only to look back on the days when barrels of wild ducks, shore birds, and pigeons were regularly sold for little or nothing at market, and thousands of big-game animals were killed only for the hides which were sold as a cheap source of leather. The plume hunters went by the board just in time to save the snowy heron and reddish egret, which they had all but exterminated. The whaling and sealing industries operated for many years without restriction.

Hunting and trapping, although for the most part now well under regulation, have taken heavy toll of certain species. Poaching, illegal hunting, and lack of protective laws still menace certain forms of game animals, and some of our more important fur animals have lacked sufficient protection. The apparently inborn urge on the part of some outdoor men to shoot every conspicuous and large living form of wildlife created a serious situation for rare species and one that can be controlled only by conservation education. Extension and improvement of travel facilities in more recent years have increased pressure on wildlife.

Drainage, cultivation, stock raising, and other necessary artificial changes of wildlife habitat have endangered many species. Most of these environmental changes could not have been avoided, yet often wildlife received no consideration when it should have been given a place in the picture.

The introduction of exotic species has often proved to be detrimental to native forms, through either predation or competition. There need be mentioned here only such instances as the introduction of the mongoose, a predator, into the West Indies and Hawaii, and game animals such as the rabbit into Australia, the American gray squirrel into England, the red deer into New Zealand, and the nongame bird, the European starling, into the United States, where it competes for

nesting sites with hole-nesting birds such as the crested flycatcher and the bluebird.

Natural environmental and ecological changes.—Most of the natural environmental changes that adversely affected species so as to hasten their extirpation probably were climatic. Some of the major climatic changes resulted in the glacial periods, or at least were associated with glaciers, the general effects of which on the flora and fauna are known to most students of biology. Glaciers caused the breaking up of the geographic range of species into discontinuous distribution areas, sometimes so small as to endanger the existence of the species. Changes of climate associated with glaciation so affected the remnant population of many species as to be their death knell, and in the late Pleistocene glacial deposits are found the remains of many of these species, and even genera, which became extinct at that time. Glacial lake transformation, from fresh-water lake to acid lake, to sphagnum bog, and to spruce woodland, completely changed environmental conditions, often to the elimination of some species. Other ecological transformations changed the environment and with it the wildlife population. Volcanic eruptions might well have caused complete annihilation of local forms of wildlife, as for example the blowing off of the top of Volcan Santa Maria, Guatemala, in 1903, and the Mount Katmai, Alaska, eruption in 1912. The eruption of Mount Pelee, Isle of Martinique, Lesser Antilles, in 1902, quite possibly exterminated the Martinique solitaire, an interesting and unique songbird.

Weather.—Weather conditions, aside from those changes permanently effected by change of climate, may have adverse effects on wildlife. Severe windstorms may, by creating clearings in the forest, actually improve local environment for some wildlife species, yet a storm of the same intensity on a marsh or a sandy area may destroy much of the wildlife. It is probable that the Cape Sable seaside sparrow, found only on the salt marshes of southwestern Florida, was wiped out of existence by the Florida hurricane of 1937. The devastating effects of drought on wildlife are fresh in our minds from conditions created by drought in waterfowl nesting areas of the Northwest less than a decade ago. Cold or wet seasons, especially during a breeding season, may often reduce populations, sometimes to the danger point.

Struggle for existence.—The "struggle for existence" is an old evolutionary term, more or less hackneyed; nevertheless, overspecialization may place a species at a disadvantage in competition with forms less specialized and better able to meet competition and changed environment. Gigantism, a type of specialization, may of itself have been a factor in the disappearance of many of the gigantic reptiles and mammals of past ages.

Disease.—Evidence clearly indicates that diseases have at times been important factors in reduction of populations of wildlife. Diseases and parasites, however, disseminate more freely in dense populations, so that the effect is to produce population fluctuations, or cycles. Beyond this initial reduction of such populations, disease is probably not as a rule an important factor in the extermination of a species.

WILDLIFE SPECIES THAT HAVE BECOME EXTINCT

Although our own country in the past has abused its wildlife population to the extent of exterminating several species, and has been negligent in many ways in preserving vanishing forms, it has not been alone in this. Before considering extinct North American animals, let us glance at the headstones of the graves of some of the foreign species. No attempt is made here to compile a complete list of extinct animals of foreign countries, and only some of the more noteworthy or conspicuous are included.

In Europe, such an important mammal as the aurochs, ancestral stock of some of our domestic cattle, which inhabited large areas of central and southern Europe, and also northern Africa, passed into the realm of vanished species in Poland in 1627. A few years later the tarpan, an ancestor of the domestic horse found on the steppes of southeastern Russia, became extinct, although a close relative, Przewalsky's or the Mongolian wild horse, still exists in small numbers in Mongolia.

In Asia, Pere David's deer that formerly inhabited parts of North China is extinct in the wild state. At the time of the Boxer Rebellion in 1900, some 200 animals, all that remained in China of this species, held in captivity in a park near Peking, were killed for food. Fortunately, a few animals had previously been sent by the Duke of Bedford to England, where about 50 are now maintained at Woburn. Steller's sea cow, a huge manatee 30 feet long or more and weighing upward of 3 tons, first brought to the attention of science in 1741, met its doom in 1768 in supplying oil and food for man. This huge manatee inhabited Copper and Bering Islands and possibly other islands in Bering Sea. The Pallas cormorant, an interesting fish-eating bird of the Commander and other Bering Sea islands, became extinct in 1852.

Among wildlife species that have been exterminated in Africa, the first to go by the acts of modern man was the blue antelope, or blaubok, which disappeared in 1799 from South Africa. From South Africa also there disappeared about 1875, through hunting, the quagga, which resembled a donkey with zebra-like stripes on its cape and neck only. Burchell's zebra became extinct in South Africa

some 25 years later. In northern Africa, in the mountains of the Algerian Sahara, the red gazelle has probably vanished for all time.

Turning now to Australia and the South Sea Islands, those giant flightless birds, the moas, disappeared from the feathered fauna of New Zealand islands, probably between A. D. 950 and 1350. Undoubtedly the last remnants vanished through the agency of man, although ancient Maori tradition and legends refer to the moa as burnt up by the "fires of Tamaten" in times long past, which may refer to its destruction by volcanic action. Archey (1941) recognizes 19 species of these birds belonging to 6 genera. In Australia itself the little plains rat-kangaroo has not been seen since 1843, and the marsupial anteater vanished in 1923.

Many forms of wildlife have become extinct in the Western Hemisphere. Some of the earlier of these to vanish were insular forms, such as Gosse's macaw from Jamaica, about 1800. The Cuban tricolored macaw became extinct in 1864, chiefly through utilization for food. The history of Guadeloupe Island, one of the Leeward Islands, portrays the extinction of three bird species, the yellow-winged green parrot, the purple Guadeloupe parakeet, and the Guadeloupe macaw. Strangely enough, an island of like name in the eastern Pacific Ocean, Guadalupe Island, has witnessed the extirpation of the Guadalupe caracara and probably the Guadalupe towhee and the Guadalupe rock wren.

Several races of mammals formerly inhabiting North America—in fact, parts of the United States—have passed into the ranks of the vanished. The big dark buffalo of the northeastern United States, the Pennsylvania bison, was last known in Pennsylvania in 1801. The Maine giant mink, nearly twice the size of our ordinary minks, that lived along the seacoasts of Maine and Nova Scotia, became extinct in 1860. The eastern puma, or cougar, was gone by about 1885. Of our grizzly bears, the first to disappear was the Texas race (1890), followed shortly by the Plains grizzly (1895), and the Tejon grizzly of the arid southwestern region of California (1898). Although the taxonomic status of the grizzly bears is not entirely clear, it is, nevertheless, certain that many races of these mammals are recognizable and that many of these have disappeared. Among these extirpated forms may be mentioned the California grizzly bear (1922), Sacramento Valley grizzly, California coast grizzly, Arizona grizzly, Black Hills grizzly, Navaho grizzly, Mount Taylor grizzly, Utah grizzly, and Chelan grizzly. Even such an insignificant mammal as the Gull Island meadow mouse could not escape extinction when its habitat on Great Gull Island, at the entrance of Long Island Sound, New York, was covered by earth moved in grading the island for fortifications some time before 1898. Another inconspicuous small mammal, the

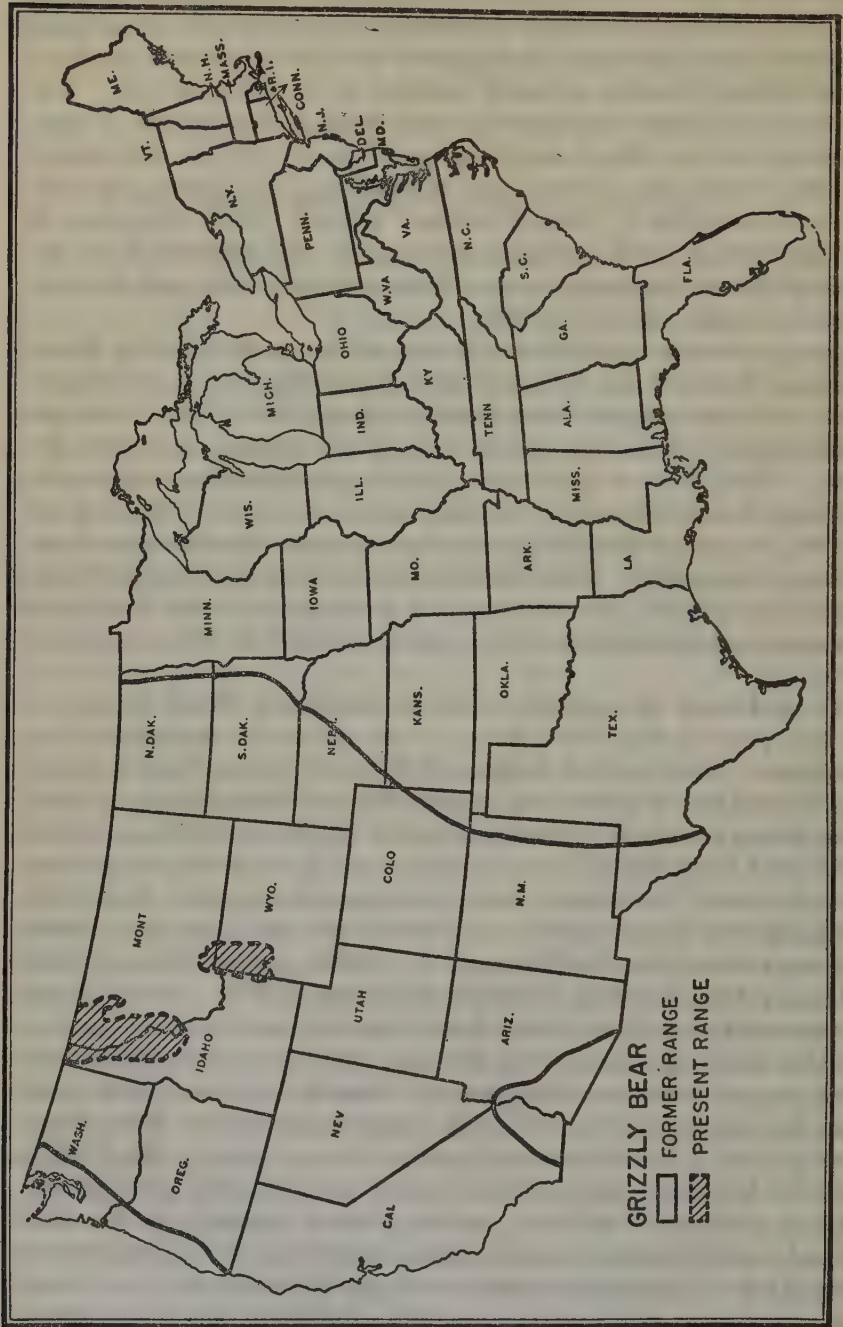


FIGURE 1.—Former range and present range of grizzly bears in the United States.

Amargosa meadow mouse, known only from a small tule marsh at a spring near Shoshone, eastern Inyo County, Calif., had vanished by 1916 after the marsh had been burned several times and used for a pasture. The largest of our elk, the Merriam elk of Arizona and New Mexico, was exterminated by 1900 or before. The Audubon or Badlands bighorn sheep of the Dakotas and eastern Montana was last known alive about 1914, and it is quite probable that the lava beds or rimrock bighorn of southeastern Oregon and northwestern Nevada has gone. No longer will any stockmen need to worry over depredations of the big Plains wolf, which ceased to exist about 1930.

Within the borders of the United States, five forms of birds are now certainly extinct, namely, the great auk (1844); the Labrador duck (1875); the passenger pigeon (last native wild bird, 1908; last survivor in captivity, which died of old age in the Cincinnati Zoological Gardens, September 1914); the heath hen, or eastern representative of the prairie chicken, was last seen alive on March 11, 1932, and can be said to be extinct in 1933; and the Carolina parakeet about 1935, or previous thereto. Two other species are probably gone, the Eskimo curlew, of which there have been only very indefinite and unsatisfactory records for recent years, and the Cape Sable seaside sparrow, probably wiped out of existence by the tropical hurricane of southern Florida in 1937.

ENDANGERED WILDLIFE SPECIES

We shall not go into details as to the status of all foreign vanishing and endangered wildlife, but we should know at least a few of the species that are in a more precarious condition in continents other than our own. Europe, through private and public game preserves, has been able to care for most of its wildlife species. The eagle owl has been persecuted and is in some danger, and the white stork, though at least up to the time of World War II well protected in Europe where it nests, has been depleted in numbers through being killed for food by natives in its African winter home. The European brown bear is becoming exceedingly rare, and the ibex and chamois are in danger, as is also the European beaver. The wisent, or European bison, became so reduced in numbers that it has been crossbred with the American bison and domestic cattle of old-lineage strain in an effort to retain some semblance of the species. Even these may now be wiped out through economic strain of wartime conditions.

We have already mentioned the status of Przewalsky's horse in Asia, but in that continent the ancestor of the donkey, the kiang, is so reduced in numbers as to be nearing the danger line. Other Asian mammals in danger of extirpation include the seladang, a huge wild ox of India; that large deer, the Malayan sambhur; and the three

species of Indian rhinoceroses—the Asiatic two-horned, the Indian one-horned, and the lesser one-horned. The last named has most likely already vanished. Many of the species of pheasants especially need attention if they are to be saved, and the Argus pheasant is actually endangered.

Africa, long known as the continent of many species of remarkable antelopes and other big-game animals, has maintained, particularly through the British and Belgian Governments, extensive game preserves, and as a rule has offered protection to wildlife. In spite of this effort to save the fauna, however, a few species have become extinct and several others are vanishing. No less than a dozen species of antelopes are endangered, among them the beautiful inyala, now probably limited to about 200 individuals in Kruger Park. The Bubal hartebeest of North Africa has become scarce, and the Cape hartebeest is reduced to about 40 animals. In the case of the bontebok of South Africa, 23 were driven in 1929 into an enclosure of 1,800 acres set up as Bontebok National Park. Of these animals, 16 survived and there has been some increase, half-domesticated. There are not over 60 bonteboks alive today. The blesbok, a closely related antelope, is in about the same status as the bontebok. Other African antelopes in danger of extirpation include the white-tailed gnu, the giant sable antelope, the giant or Lord Darby's eland, the gemsbok, and the addax. The rare and unique okapi, modified forest giraffe of the Congo forests, is decreasing in numbers. Other mammals in serious danger in Africa include the Abyssinian ibex, mountain zebra, white rhinoceros, hippopotamus, South African elephant, and gorilla. Among several African birds endangered is the unique shoebill stork.

Australia, the land of marsupials and many strange animals, is on the verge of losing more of its unique species. Special legislation prohibiting the taking of certain fur animals and forbidding even the exportation of the fur or any part of the animal may save some of these species. Especially in danger is the koala, often nicknamed the "teddy bear," and the gray wallaby, one of the larger kangaroos. The estimated population of koalas in Australia decreased from 250,000 to 1,100 in a few years before the establishment of a preserve for the species on Phillip Island, Victoria, about 1938. In February 1942 there were 590 koalas in this colony. The hairy-nosed wombat and the Tasmanian wolf, or thylacine, are both nearing extermination. It is doubtful if the beautiful lyrebird can be saved. The hawk parrot, as well as several other parrot species, are on the way to oblivion.

In South America protection may have come too late to save in its native habitat the now rare fur bearer, the chinchilla, as well as the guanaco, wild ancestor of the domesticated llama, and the vicuna, native wild ancestor of the domesticated alpaca. Three species of the

ostrichlike bird, the rhea, are near the vanishing point in South America, as are the bell bird and the steamer ducks, flightless ducks of Tierra del Fuego.

North America, where our interests more naturally center, has a long list of endangered wildlife races, at least 50 in number, of which all except one or two marine forms occur in the United States or its Territories. Several of the grizzly bears have already gone, and within the States it would seem that Yellowstone National Park and Glacier National Park offer about the only real hope for their preservation. Black bears as a group are reasonably safe, yet the Florida black bear is reduced to less than 500 and is decreasing in numbers. That frosty-gray bear of the black bear group, the glacier bear of Alaska, is so scarce as to face extinction. Its remote and almost inaccessible habitat may save it.

The fisher, the marten, and the wolverine have all been trapped so extensively for fur that they are almost gone from the United States and have been reduced to the danger point everywhere in North America. The black-footed ferret, formerly found on the plains with a geographic range almost coinciding with that of the prairie dog, was never a common mammal, but has become rarer and rarer, until now it is seldom reported. The southern sea otter was a few years ago believed to be extinct, when unexpectedly a small herd was discovered south of Carmel, Monterey County, on the coast of California. This herd now numbers about 300 animals or more, though recently tending to become scattered. It is protected and guarded carefully, and with proper management the race may be saved from extinction.

The unsuspecting little kit fox of our western plains was not only easily trapped for its fur but also frequently was caught in traps set for coyotes and other animals. No restrictions seem to have been placed on killing it, with the result that what was once a common mammal is now rare, and in many regions extirpated. The timber wolf of the Northeastern States could hardly be expected to withstand settlements and civilization and has almost succumbed to the inevitable. In fact, all the large wolves of the United States are endangered. The eastern puma, or cougar, has been exterminated. Among the other cougars, the Florida subspecies is the most endangered, there being probably less than 25 individuals left.

Several of our seals are so reduced in numbers as to cause serious concern for them. The Guadalupe fur seal of the west coast of Mexico has reached too low a population for its safety, and may even have vanished, and both the West Indian monk seal and the Pacific monk seal have become rare and reduced to local habitats. That oddity of seals, the elephant seal of the Pacific coast, has shown some recovery during the past decade, but is still in a precarious condition. On the

North Atlantic coast, the beautiful hooded seal has been hunted for oil and fur until it, too, is in danger. The Pacific walrus, while in some danger, is not reduced to the vanishing stage, as appears to be the case with the Atlantic walrus.

We correctly think of the white-tailed deer as our most abundant big-game animal, yet the Pacific white-tail is down to about 1,000 animals, and was supposed to have a much lower population until Dr. Victor B. Scheffer (1940) gave an account of a herd at the mouth of the Columbia River. The key deer, inhabiting a few of the lower Florida keys, is very rare, local in distribution, and probably does not number more than 40 individuals. It was reduced by the hurricane of 1937, and has been overhunted and subjected to poaching until only a few remain.

When the mad rush for gold was on in California during the middle of the nineteenth century, the great valley of California, the combined valleys of the San Joaquin and the Sacramento Rivers, abounded in a small elk with simple antlers, the California valley or tule elk. It soon became scarce. A remnant was protected on the Miller and Lux Ranch, Buttonwillow, Kern County, Calif. In an effort to save these animals, which may have reached a total of 350 or 400 animals in 1921, some were transplanted in Yosemite and Sequoia National Parks. In 1933 all of these, and several from the Buttonwillow herd, were transferred to a reservation with good elk-pasture features in Owens Valley. Today there probably exist not over 150 of these elk, nearly all in Owens Valley, though a few may still survive on the Buttonwillow Ranch.

The last woodland caribou seen in Maine were near Mount Katahdin in 1908. They had disappeared from New Hampshire and Vermont about the middle of the nineteenth century. Fifteen occur in northern Minnesota, only two of which are native, the others being from stock brought in from Saskatchewan. In Canada, also, the woodland caribou is vanishing, and in many regions where it was once common it is now gone. The eastern moose, while not in so much immediate danger as the woodland caribou, is nevertheless rapidly approaching a precarious situation.

All our bighorn sheep should give us cause for worry. Two forms are in especial danger. The Sierra bighorn may be reduced to less than 75 animals, and the Texas bighorn, at one time thought to be extirpated, is reduced to some 125 animals scattered in 6 or 8 mountain ranges, and its fight for survival in competition with domestic sheep and goats and in the face of illegal hunting is almost hopeless unless reservation provisions are offered it. The desert bighorn has, we hope, been saved by the establishment of national refuges for its preservation in Arizona and Nevada.

Unique among all mammals, the odd-looking musk ox, which resembles somewhat a miniature shaggy-haired buffalo and combines certain features of the cattle tribe on the one hand with those of the sheep on the other, is dwindling in numbers. Although formerly occurring in the barren grounds from northern Alaska to eastern Greenland, it is at present found native only on the east coast of Greenland and in Arctic barrens directly north and northwest of Hudson Bay as far as about latitude 83°. Even within these ranges musk oxen inhabit only certain areas, and there are immense expanses where none occurs. Attempts are being made by the Canadian Government to colonize the species in the Dominion. Of an initial stock of 34 musk oxen brought by the United States Fish and Wildlife Service from Greenland, via Norway and the United States, to Alaska in 1930, and held at the United States Biological Survey Experiment Station, Fairbanks, for study and acclimatization, 4 animals were introduced on Nunivak Island National Wildlife Refuge in Bering Sea in 1935 and 27 in 1936. This herd had increased to more than 100 animals in 1941.

Stories and legends about mermaids originated in superstitions about those peculiar aquatic mammals, the dugongs and the manatees. In their present distribution, dugongs inhabit only parts of the Eastern Hemisphere, whereas the three species of manatees occur only in the Atlantic coastal waters of America from Florida to Brazil. The manatees are harmless mammals that feed on aquatic vegetation. All may be included in the endangered list, but the status of the most northerly form, the Florida manatee, is especially critical. Ample legal protection, it would seem, is afforded the animal, but laws are not always enforced, and many individuals are wantonly shot. Sudden drops in temperature to freezing, or two or three nights of freezing weather, often kill manatees.

Even some of our smaller game mammals need especial protection if we expect to continue them as a part of our American life. The northeastern fox squirrel and the mangrove fox squirrel are both at such a low population as to be near the vanishing point.

With their high value for oil and other commercial products, all the large whales face probable serious reduction in numbers. Three species are now at the danger point. The gray whale, found offshore in the North Pacific and at one time important in the whaling industry, is so reduced in numbers that only a few are procured annually. The bowhead whale, some 50 feet long and with massive, heavy head, formerly occurred throughout the oceans near the North Pole. It became extirpated in the North Atlantic some 50 years ago and is now limited to a sparse population in Bering Sea and toward the northeast thereof. The North Atlantic right whale, another massive whale that produced a heavy yield of oil and whalebone, was so eagerly

sought by whalers in the North Atlantic that it has been reduced almost to extirpation. This species has long ceased to be an item of commercial importance. The Whaling Treaty Act of 1936 should tend toward conservation of whales. Nevertheless, during 1937-38 there were 54,664 whales killed, a yearly high for all time. Of these, 46,039 were captured in the Antarctic region. What effect World War II has had on whales and the whaling industry is problematic. There was need for whale products in war industries, but there was also demand for the use of ships employed in whaling for other war purposes. Moreover, the risk in whaling during war times tended to curtail the industry.

There are many North American birds that are in a more or less precarious situation as to their future existence. Some of these, such as Leach's petrel, reddish egret, Franklin's grouse, southern white-tailed ptarmigan, sage hen, golden plover, and upland plover, it would appear are holding their own, or possibly are on the uptrend, though once greatly reduced in numbers and hard pressed. Others are in the more precarious class. The great white heron population of extreme southern Florida shows no appreciable increase, although protection is afforded these birds on the Great White Heron National Wildlife Refuge, where about half of all birds dwell. In October 1938 Alexander Sprunt, Jr., counted a total of 585 great white herons; in February 1941 Harold L. Peters counted 551, of which 290 were on the Great White Heron National Wildlife Refuge. The roseate spoonbill, beautifully colored and grotesque of bill as the name implies, is possibly in more danger as a nester in the United States than the great white heron, though actually at present more birds exist. It is found in the same general region of Florida as the great white heron, but has a supplementary chance for survival in a larger colony in Texas. There are also a considerable number of the birds in Mexico. The Florida nesting birds are decreasing in numbers. The Texas nesters have increased, but are in constant danger of destruction through oil development.

Another strictly American bird being preserved by refuge management is the trumpeter swan, the largest of American waterfowl. Formerly nesting from northwestern Iowa and central Nebraska northwesterly to central British Columbia and Alberta, it is now limited during the breeding season to the vicinity of Yellowstone National Park, Wyo., and the Red Rock Lakes National Wildlife Refuge, Mont., and to a refuge at an undesignated locality in western Canada. At each of these breeding areas, the birds are being carefully guarded. In the Yellowstone-Red Rock Lakes regions there has been an increase from 33 birds in 1934 to 211 birds in 1941. In Hawaii, the nene, or Hawaiian goose, has faced destruction by man and the mongoose.

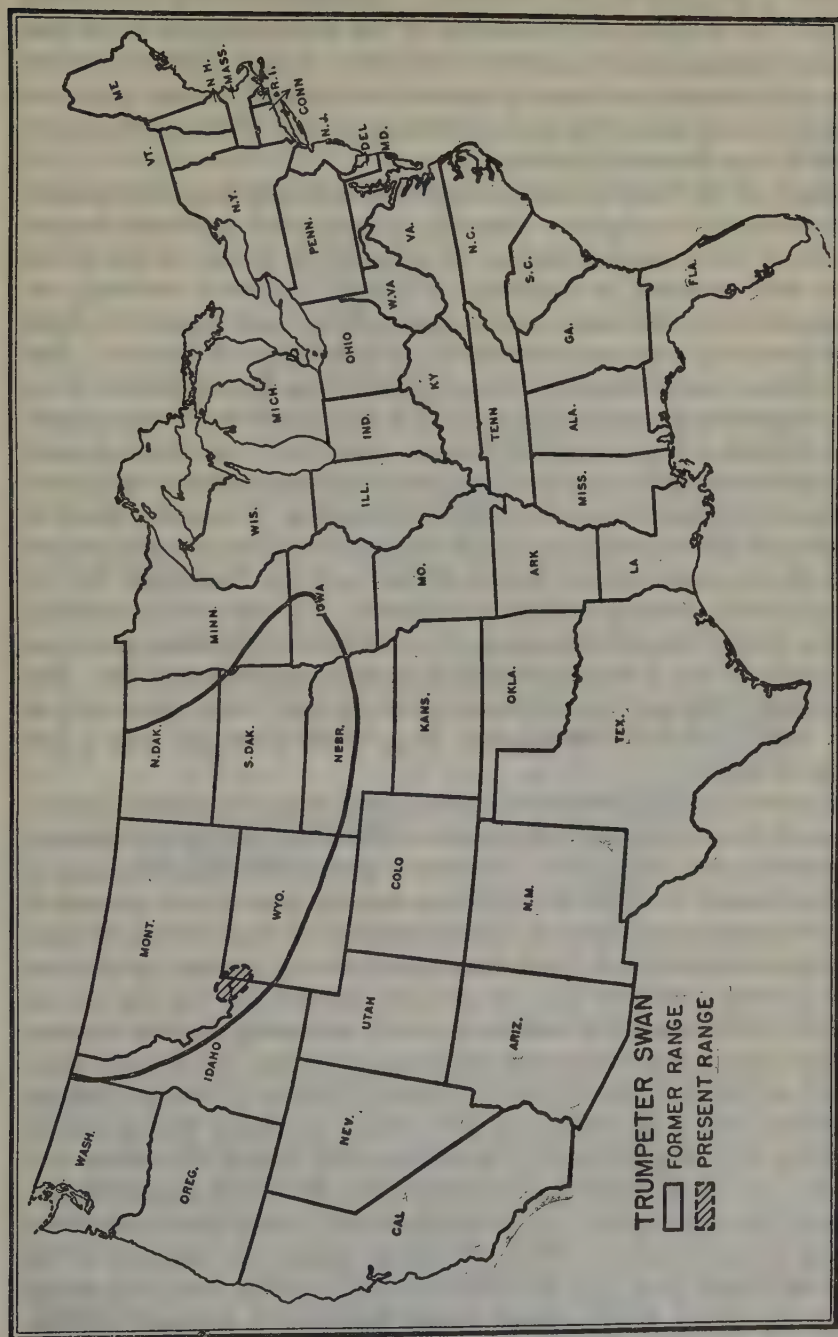


FIGURE 2.—Former breeding range and present breeding range of trumpeter swans in the United States.

There may be 100 or more of these dry-land geese in captivity, but the species is probably reduced to about 25 individuals in its native wild state. The Laysan teal is another of the duck-and-geese tribe confined to Laysan Island southwest of Hawaii. It is at an extremely low ebb, and though inhabiting a national bird refuge, it may pass into history at any time, if it has not already gone. There were only 14 birds left on the island in 1923.

Many of our birds of prey, even though actually beneficial species, have been shot on sight as harmful, or considered legitimate targets on which to test marksmanship. Practically all species of this group have been reduced in numbers. Probably the most seriously endangered is the California condor, masterful airman of graceful flight and grandeur, and man's benefactor as a destroyer of carrion. The California condor formerly ranged west of the Sierra Nevada from Washington to Lower California, and in the days of the "forty-niners" was not rare. It is now reduced to not more than 70 individuals, most of which make their home in a comparatively small isolated valley in a range of mountains in southwestern California. Two other birds of graceful flight and beauty and both of harmless habits, the white-tailed kite of the southwestern United States and the Everglade kite of Florida, are extremely reduced in numbers. The whitetail is probably in less danger than the Everglade, since its present distribution is more extensive and it is known to nest in several scattered colonies. The Everglade kite, however, is known to nest in the United States only in the vicinity of Lake Okeechobee, Fla., where there are only a few pairs of birds.

Three of our gallinaceous birds are approaching the vanishing point. None of the existing races of prairie chickens is in any too satisfactory a position, and one of them, Attwater's prairie chicken, is reduced to approximately 8,000 birds inhabiting scarcely more than 5 percent of the former range of the race. The population of these prairie chickens has been reduced not only by hunting but also by general agricultural and grazing practices, and by excessive rainfall during the nesting season. The masked bobwhite, formerly occurring in fair numbers within the United States near the Mexican border, has become extirpated except for local colonies in Sonora, Mexico. From this meager Mexican supply an effort has been made to restock the species in Arizona and New Mexico. The eastern wild turkey, the native wild turkey of our Atlantic coast colonists, has all but disappeared as a pure-strain wild turkey. A few of them still inhabit the region of the lower Santee River in South Carolina; under the auspices of the United States Fish and Wildlife Service, 15 birds from this region were placed on Bull's Island, South Carolina, a national wildlife refuge, in 1939-40. This stock has increased, and will provide another

flock of pure-strain wild birds. Elsewhere there are birds that show characteristics of the original native stock, but a large portion of the population shows crossing with domestic turkeys.

The whooping crane, a white bird nearly man high, formerly occurred during migration from the Atlantic coast south to Georgia and west to the foot of the Rocky Mountains, was known to nest from Iowa and Nebraska north and northwest to Hudson Bay and Mackenzie, and wintered in huge flocks in the Gulf States. Being big and

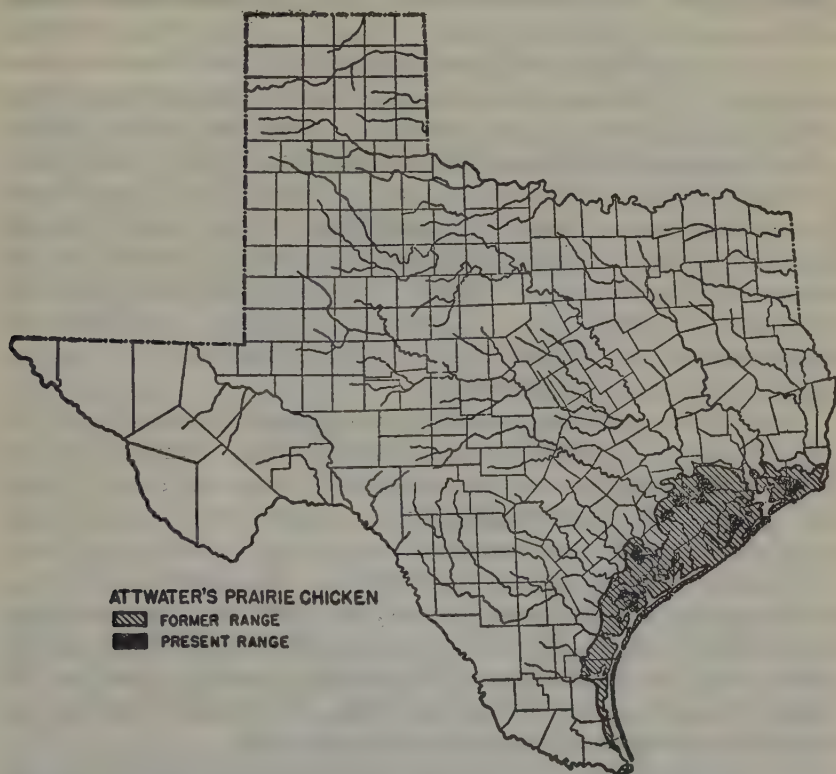


FIGURE 3.—Former range and present range of Attwater's prairie chicken in Texas.

conspicuous, and an inhabitant of the open places, it afforded "something to shoot at" for the unprincipled gunner who was out only to kill. It was reduced to a low population of possibly not more than 25 individuals by about 1925, and even today there are almost certainly less than 100 living. They no longer nest in the United States, and the wintering flocks sojourn chiefly in Texas. Each winter a few visit the Aransas National Wildlife Refuge in southern Texas, 26 individuals having been observed there during the winter of 1940-41. The Florida sandhill crane, a grayish bird smaller than the whooping crane, confined to only a few nesting localities in Florida and one in

Georgia, is dwindling in numbers and can be saved only by diligent protection.

Several shore birds are becoming scarce, even though provided protection through the Migratory Bird Treaty Act. The last specimen record of an Eskimo curlew for the United States was in Nebraska in April 1915, though a bird was collected in Argentina in January 1925. One was reported as a sight record from Hastings, Nebr., April 8, 1926. There are no reliable records since then, and the species is probably gone. Of other shore birds, the Hudsonian godwit seems to be nearest the vanishing point. It nests on the Barren Grounds from Alaska to Hudson Bay, and migrates to South America where it winters. It became greatly reduced during the game-marketing days of the eighties and nineties and has never been able to recover.

The largest and most magnificent woodpecker of the United States, the ivory-billed woodpecker, is now reduced to a few individuals. Probably all these, and certainly most of them, are in a heavily forested tract in Louisiana. Dense forests of large trees are essential for the existence of the ivorybill. Unless its Louisiana home can be saved from the lumberman's ax, the ivorybill is doomed. And with the urgent war call of "Timber! Timber!" the outlook for retaining this species in our fauna is not hopeful.

Three of our small passerine birds have approached the danger line. One of these, the dusky kinglet, a midget bird of Guadalupe Island, Lower California, may now have followed other vanished birds on that island. Bachman's warbler of the southeastern United States, always in recent times a rare bird, barely maintains its population, and in general appears to be on the decline. The Ipswich sparrow, a species related to the savanna sparrow, has a breeding range restricted to small Sable Island, Nova Scotia, and in winter is found from there south along the sand dunes of the Atlantic coast to Georgia. On Sable Island it nests only near the beach. Wave action from severe storms may at any time destroy its nesting habitat.

Both the American crocodile and the Mississippi alligator have decreased in numbers in their habitats in the swamps of the Southeastern States. The crocodile never occurred within our United States boundaries proper except in extreme southern Florida. It differs from the alligator in its longer and slenderer body, its much more pointed snout, and longer teeth. Both the crocodile and the alligator have been hunted for their hides for use in leather manufacture. Many of them have also been wantonly killed out of sheer prejudice and hatred for an ungainly reptilian with an unfriendly appearance. The catching of the young of both species and their sale as pets to be transplanted to a more northern climate unsuited to them has killed hundreds. The crocodile is almost a relic of the past in the United States. The alligator, under proper protection, will probably stay with us.

Of our highly edible fishes, two species of sturgeons, the common and the lake, have been so reduced in numbers, largely by commercial fisheries, that they have not only become of little commercial importance but are in actual danger of extinction. The status of Lake Superior whitefish, to many of us the grandest of all table fish, is almost the same as that of the sturgeons. And on our eastern coast, the thousands of Atlantic salmon that formerly, early in summer, ascended many of the New England streams to spawn, now migrate only by hundreds to one or two rivers, more notably the Penobscot.

SOME SPECIES THAT HAVE RECOVERED

Dark as the picture is for many of the wildlife forms mentioned, there is a light of hope for saving some of them if appropriate action is taken. Examples we have of wildlife species that have recovered after being on the verge of extinction offer that illumination. The American bison roamed the prairies and plains of the United States and Canada in herds that in pioneer times certainly aggregated more than 50,000,000 animals. By the close of the nineteenth century, the population had probably reached its low at a total of about 800 animals. The American Bison Society estimated 1,917 living animals in 1908. Shortly afterward, through the efforts of that Society, the National Bison Range was established under the administration of the Biological Survey on land formerly a part of the Flathead Indian Reservation, Montana. It was stocked October 17, 1909, with 37 bison, all but one from a private herd at Kalispell, Mont. This was really the beginning of the up-building of the American bison population. Today there are more than 6,000 bison in the United States, mostly confined to ranches, parks, and refuges, and another possible 30,000 on refuges in Canada, a total of not less than 35,000. Nineteen bison from the National Bison Range were introduced into the Big Delta region, near Fairbanks, Alaska, and had in 1941 increased to more than 200 animals. In this region they are given free range. Modern civilization and agricultural practices in most localities in the United States no longer make possible the free-ranging of vast migrating hordes of big-game animals. We can, nevertheless, save a species from extinction, as witness the bison.

That peculiarly American mammal, the prong-horned antelope, through protection in refuges and by management and hunting control, has increased from a low of about 30,000 in 1920 to 240,000 in 1943. And the American elk, or wapiti, by transplantation of individuals of the Rocky Mountain subspecies, mainly from Yellowstone National Park and the National Elk Refuge in northwestern Wyoming, has been reestablished in many localities where it formerly dwelt. A few bands of elk have even been established in localities outside their ancestral distribution, including herds of Rocky Mountain elk in south-

western Utah and Nevada, and tule elk in eastern California. The combined populations of all forms of elk have increased in the United States from a low of near 20,000 in 1905 to more than 225,000 in 1943.

The action taken to conserve the Alaska fur seal is an outstanding example of what can be done to save an animal from extinction and to restore a valuable natural resource.

Briefly outlined, the history may begin with a fur seal population of more than 4,000,000 animals in 1867, when the United States purchased Alaska. Commercial exploitation, with its associated pelagic sealing, or taking of seals at sea, and its almost unrestricted killing of seals, rapidly reduced the population. By 1911 the population had been reduced to 125,000 seals, less than the annual kill in some previous years. On December 15, 1911, a convention for the preservation and protection of fur seals was entered into by the United States, England, Canada, Japan, and the Union of Soviet Socialist Republics. Pelagic sealing by the nationals of each country was abolished. Management of fur seals on the breeding rookeries was left chiefly to the nation having jurisdiction over the locality. The United States, therefore, had charge of the great seal rookeries on the Pribilof Islands, probably involving more than 85 percent of the breeding stock. Provision was made for each of the nations to turn over to other nations of the convention a percentage of the seal skins taken on its shores. Under this protection, the seal herds increased to about 2,300,000 in 1941, and under managed cropping 800,000 fur seal pelts were harvested in 20 years, from 1921 to 1940. The convention, however, was terminated on October 23, 1941, Japan having withdrawn after 1 year's notification of her intention.

There are several species of birds that have made recovery after being near the border of death as a species. Possibly among the most notable of these are the American egret and the snowy heron. Both of these species were nearly wiped out by plume hunters who sought the adult birds during the breeding season in order to procure feathers for millinery purposes. The American egret, transcontinental over the southern United States, has now become a common bird, and it would seem may have extended its breeding range northward beyond its ancestral range. The snowy heron, although not showing the rebound of its sister heron, is nevertheless no longer in serious danger. That most beautiful of all American ducks, the wood duck, has also increased from a low population to one sufficient to insure, with ample protection, the continuance of the species.

METHODS OF PRESERVING SPECIES

The most important factor in preserving wildlife species is self-control by man so he will no longer be the most destructive animal.

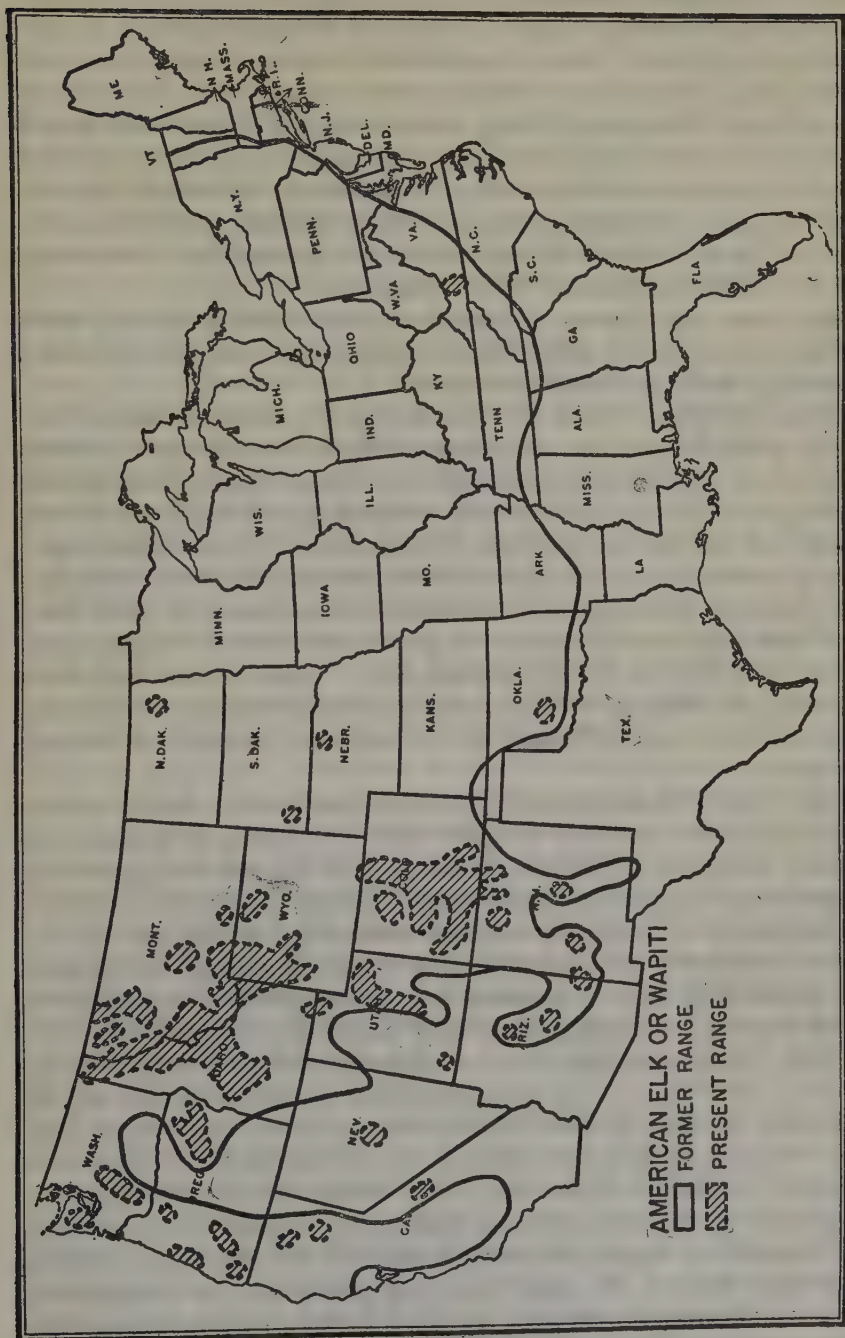


FIGURE 4.—Former range and present range of the American elk in the United States.

Such control is making progress, though often against the inclinations of the man who sees in wildlife only an easy means for immediate self-gain without regard to his own future or that of the following generations. General methods of conservation are now well formulated. Possibilities for improvement naturally will present themselves. The essential thing is to act when we know what should be done. Federal, State, and County governments and national and local organizations all have a hand in this work. When a widely distributed species is endangered, however, it becomes a national problem, and as such should be entrusted to our national wildlife agency, the United States Fish and Wildlife Service.

Adequate organization is needed to administer funds and work projects, to supervise activities, to enforce legal protective acts, and to manage wildlife and wildlife areas.

Legal protection, both Federal and State, is a necessity. The many State fish, game, and other wildlife laws are not familiar in detail to most of my readers, but we all know there are many such serving a useful purpose. Among national laws there is the famous Lacey Act (act of May 25, 1900, 31 Stat. 187—18 U. S. C. 395) regulating interstate commerce in wild birds and other animals. A similar law passed in 1926 applies to interstate transportation of black bass. The bald eagle, our national bird symbol, has been given legal protection (act of June 8, 1940, 54 Stat. 250). Other Federal laws have provided for national wildlife refuges or the protection of wild animals and birds and their eggs, and Government property on Federal refuges.

The range of many species of wildlife, particularly during migrations, may cover territory of more than one nation, or species may inhabit international waters. When such is the case and protection is necessary, resort is made to treaties among the nations involved. A convention covering the essential reasons for acting and the objective and means of accomplishment is entered into by the nations. An enabling act is then necessary for enforcement of the convention by each nation. Thus Migratory Bird Treaty Act (act of July 3, 1918, 40 Stat. 755, as amended by act of June 20, 1936, 49 Stat. 1555—16 U. S. C. 703—711) and the Migratory Bird Conservation Act (act of February 18, 1929, 45 Stat. 1222, as amended June 15, 1935, 49 Stat. 381—16 U. S. C. 715) are enabling acts to enforce the "Convention between the United States and Great Britain for the Protection of Migratory Birds in the United States and Canada," as signed in Washington on August 16, 1916, ratified by both the United States and Great Britain the same year, and proclaimed on December 8, 1916. A "Convention between the United States of America and the United Mexican States for the Protection of Migratory Birds and

Game Animals" was signed at Mexico City, February 7, 1936, ratified by the United States on October 8, 1936, and by Mexico on February 12, 1937, and proclaimed on March 15, 1937 (50 Stat. 1311).

Among other important treaties relating to wildlife is the Whale Treaty. The "Convention for the Regulation of Whaling" was signed by representatives of 26 countries, including the United States, at Geneva on March 16, 1932, and was approved for ratification by the United States Senate on June 10, 1932. The enabling act put the treaty into effect on May 1, 1936. An enabling act may give authority for action, but may neglect appropriations for operations. Such is the case with the Whaling Treaty Act. The important Fur Seal Treaty has heretofore been mentioned.

On October 12, 1940, in the Pan American Building at Washington, D. C., representatives of 13 American republics signed the "Inter-American Convention on Nature Protection and Wildlife Preservation." Since then others have approved, and now 17 have signed the pact. When this treaty is completed and in operation, it should aid materially in the protection of many forms of wildlife, more especially birds, such as some of the curlews and plovers, that might migrate between the two continents.

Permanent refuges, sanctuaries, parks, primitive or wilderness areas, or whatever you may call them, carefully selected and maintained as the optimum habitat for the species, are essential for the preservation of endangered wildlife. By refined definition the terms "refuge," "sanctuary," "park," and "primitive area" have distinct and different meanings. Sometimes a refuge is called a preserve, reservation, or range. Often, however, in actual usage in proper names, any one name may apply to an area established for the preservation of nature, including wildlife, or primarily for saving a species. The old adage "What's in a name?" here applies. All of them serving for wildlife preservation, we find such names as the Wichita Mountains Wildlife Refuge in Oklahoma; the Desert Game Range in Nevada; the Thelon Game Sanctuary in Canada; the Yellowstone National Park in Wyoming; the Kruger National Park in the Union of South Africa; the Parc National Albert in the Belgian Congo; and the Sierra Primitive Area in California.

Frequently, in order to insure suitable environment, a refuge is established in an area including the remnant of a species, and from that remnant as breeding stock effort is made to increase the population. Several refuges in the United States have been established in this way, such as the Sheldon National Antelope Refuge and the Charles Sheldon Antelope Range, Nevada, for prong-horned antelopes; the Red Rock Lakes National Wildlife Refuge, Montana, for trumpeter swans; the National Elk Refuge in Wyoming, and the

National Great White Heron Refuge in Florida. Often transplantation of stock to a suitable area is necessary. This was the case in the establishment of bison on the National Bison Range, Montana; musk oxen on the Nunivak Island National Wildlife Refuge, Alaska; bison, elk, and prong-horned antelopes on the Wichita Mountains National Wildlife Refuge, Oklahoma; and eastern wild turkeys on Bull's Island, South Carolina.

Improvement of habitat, always based on research as to the needed environment, may change living conditions of a small population of a species so as to be the determining factor in its preservation. Artificial means thus applied for wildlife restoration should tend to restore the natural environment of the species or create adaptable substitutes. The means are many and include various types of water restoration; change in vegetative types used by wildlife for food and cover; creation of nesting sites; and control of predators and parasites, often necessary when a wildlife type is nearing the vanishing point.

Domestication and crossbreeding have been suggested as having a place in saving an endangered wildlife species, but these methods should be employed only as a last resort. Species so treated for many generations, such as the dog, the cat, the horse, the water buffalo, the ox, the sheep, the chicken, the turkey, and others, have all lost the characteristics of the wild ancestral stock and developed into many varieties. Fur farming may save the silver fox, a color variation of the red fox, but in so doing it may so change its characteristics through rearing that the native type would vanish. In order to save the European bison, or wisent, it has been crossbred with an old-lineage strain of domestic cattle in Germany and with the American bison in the Ukraine, Union of Soviet Socialist Republics.

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1940. The passing of the lyre-bird. New York Zool. Soc. Bull., vol. 63, No. 5, pp. 146-152, illus. October.

The above titles represent only a few of many writings on endangered species and their conservation. Others are to be found in the publications of scientific and conservation organizations, such as the following:

American Bison Society, New York Zoological Park, New York, N. Y.

American Committee on International Wildlife Protection, New York Zoological Park, New York, N. Y.

- American Ornithologists' Union, Dr. Lawrence E. Hicks, Secretary, Ohio State University, Columbus, Ohio.
- American Society of Mammalogists, Dr. Emmet T. Hooper, Secretary, University of Michigan, Ann Arbor, Mich.
- American Wildlife Institute, Washington, D. C.
- Comité Belge pour la Protection de la Nature, Brussels, Belgium.
- Emergency Conservation Committee, 734 Lexington Avenue, New York, N. Y.
- Fish and Wildlife Service, U. S. Department of the Interior, Chicago, Ill.
- National Audubon Society, 1006 Fifth Avenue, New York, N. Y.
- National Park Service, U. S. Department of the Interior, Chicago, Ill.
- Office International pour la Protection de la Nature, Brussels, Belgium.
- Society for the Preservation of the Fauna of the Empire, Hertford, England.



1. AQUARELLE OF THE DODO.

(Attributed to Charles Collins, ca. A. D. 1736. Original drawing from the Taylor White Collection in the Blacker Library of Zoology, McGill University, Montreal, Canada. Reproduced from color plate in *An Introduction to the Literature of Vertebrate Zoology*, by Casey A. Wood, Oxford University Press, 1931.)



2. PRZEWALSKY'S HORSE, OR A NEAR RELATIVE, IN NATIONAL ZOOLOGICAL PARK.

(Photograph by Ernest P. Walker.)



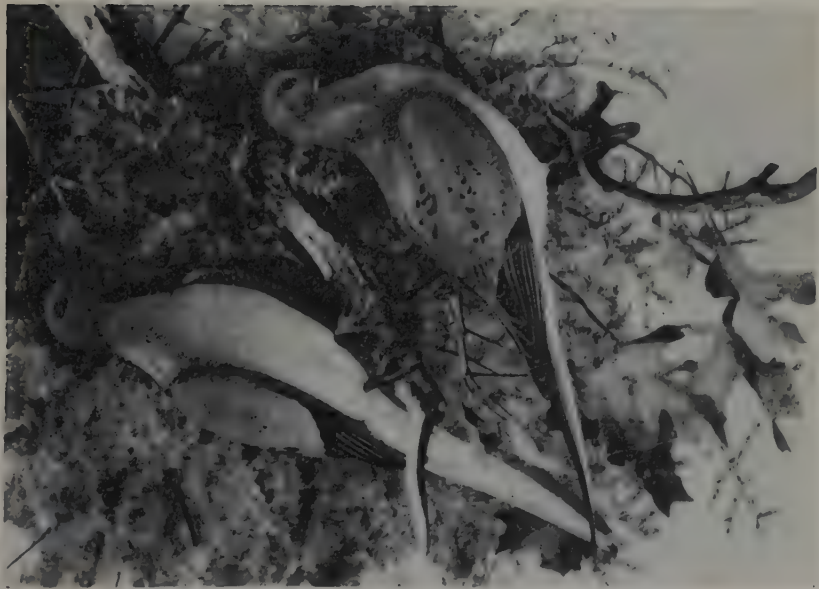
1. PÈRE DAVID'S DEER.

(Copy of color plate (IV) by J. Hüet accompanying the original description by Alphonse Milne Edwards in Archives du Museum d'Histoire Naturelle de Paris, 1866.)



2. GRIZZLY BEAR IN THE WILDS IN NORTHWESTERN WYOMING.

(Photograph by Frederick K. Vreeland.)



1. PASSENGER PIGEONS.
(From *The Passenger Pigeon*, by W. B. Mershon, Outing Publishing Company, New York, N. Y.)



2. THE LAST HEATH HEN, MARTHA'S VINEYARD, MASS.,
AUGUST 1931.



1. A PAIR OF EUROPEAN BISON, OR WISENT, LANGSJÖ, SWEDEN, ABOUT 1924
(Photograph from Swedish Traffic Bureau.)



2. WHITE-TAILED GNU IN NATIONAL ZOOLOGICAL PARK.
(Photograph by Ernest P. Walker.)



1. FEMALE VICUNA, SUCRE, BOLIVIA, JULY 1943.

(Photograph by Raymond M. Gilmore.)



2. BLACK-FOOTED FERRET ON CROW INDIAN RESERVATION, MONT., NOVEMBER 1927.

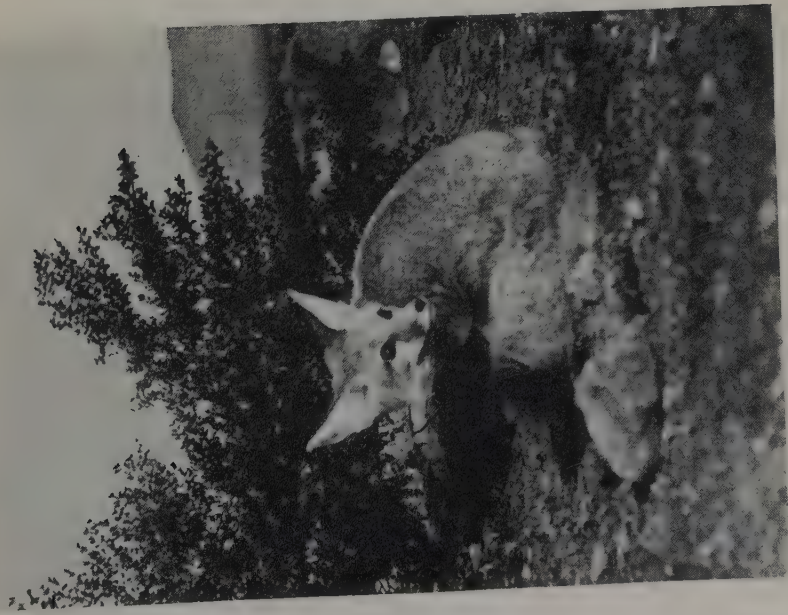
(Photograph by E. Cates.)



1. A YEARLING PACIFIC MONK SEAL, OCEAN ISLAND, HAWAII, APRIL 1923.
(Photograph by Alexander Wetmore.)



2. PACIFIC WALRUS, ALASKA



1. DESERT FOX, A CLOSE RELATIVE OF THE KIT FOX.
LONE WILLOW SPRING, CALIF.



2. CALIFORNIA TULE ELK, YOSEMITE NATIONAL PARK,
CALIF.
(Photograph from Besto Studio, Yosemite National Park.)



1. DESERT BIGHORN, OR NELSON'S MOUNTAIN SHEEP.

A middle-aged ram at Boulder Canyon Wildlife Refuge, Nev.



2. MUSK OX.

Middle-aged bull in pasture at the former Biological Survey Experimental Range, College, Alaska, prior to shipment of the herd to Nunivak Island, June 19, 1935.



TRUMPETER SWAN, RED ROCK LAKES NATIONAL WILDLIFE REFUGE, MONT



1. CALIFORNIA CONDOR IN NATIONAL ZOOLOGICAL PARK.
(Photograph from National Zoological Park.)



2. WHOOPING CRANES, ARANSAS NATIONAL WILDLIFE REFUGE, TEX.



1. AMERICAN CROCODILE IN NATIONAL ZOOLOGICAL PARK.

(Courtesy of Ernest P. Walker.)



2. AMERICAN BISON BULL ON RIVER BAR ON BISON RANGE ABOVE JARVIS CREEK, ALASKA, AUGUST 1939.

Bison were introduced into this part of Alaska and are doing well.

Smithsonian Report, 1945. — Jackson



1. AMERICAN EGRET, GEORGIA, 1936.



2. ALASKA BALD EAGLE, NEAR SEWARD, ALASKA.



1. ALASKA FUR SEAL ROOKERY, PRIBILOF ISLANDS, ALASKA.



2. PRONG-HORNED ANTELOPE AT WATER ON THE CHARLES SHELDON ANTELOPE REFUGE, NEV.

LIVING WITH THE BOLL WEEVIL FOR FIFTY YEARS

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U. S. Department of Agriculture

[With 10 plates]

"*Anthonomus grandis*, the evil spirit that dwelleth amongst us" was the text used by Dr. W. D. Hunter in describing to a Texas colored congregation the recently established boll weevil that was destroying the cotton crop on which they depended for daily bread. This reddish-brown snout beetle (pl. 1, fig. 1), measuring about one-fourth inch in length and one-third as wide, is a native of Mexico or Central America that existed in obscurity on the wild and small plantings of cotton until it immigrated to the United States a little more than 50 years ago. Since the boll weevil reached the abundant food supply provided by the almost continuous fields of cotton in the South, it has become the No. 1 cotton pest and has affected the economic and social welfare of more Americans than any other insect.

The boll weevil was first described in 1843 by the Swedish entomologist Boheman from specimens received from Vera Cruz, Mexico, and was next mentioned in the literature in 1870 by the German entomologist Suffrian as occurring in Cuba. Nothing was known of its food plants or habits until 1880, when the United States Commissioner of Agriculture received a communication from Dr. Edward Palmer describing the serious damage to cotton and specimens of weevils collected near Monclova, Coahuila, Mexico.

The first report of its occurrence in the United States came to the attention of the United States Department of Agriculture in the fall of 1894 from Brownsville, Tex., where the weevil had crossed the border before our frontiers were as well protected by quarantines as they are today. Investigations that fall by Dr. C. H. T. Townsend of the then Division of Entomology showed that the boll weevil was established in several southern Texas counties and had probably been

¹ Mr. Loftin died January 16, 1946.

present since 1892. He reported briefly on the life history and habits of the boll weevil, recommended the destruction of cotton stalks to kill the overwintering weevils, and the establishment of a noncotton zone to prevent further spread. At that time the value and practicability of pest eradication was not recognized by the public, and no steps were taken to deport this undesirable alien.

By 1895 the boll weevil had spread northward to San Antonio and eastward to Wharton, Tex., and was causing such serious damage that Dr. C. W. Dabney, the Assistant Secretary of Agriculture, upon recommendation of Dr. L. O. Howard, Chief of the Division of Entomology, appeared before the Texas Legislature urging the enactment of a pest law and the creation of a noncotton zone to prevent further spread into the Cotton Belt, but unfortunately this legislation failed to pass. The spread continued, particularly to the north and east (fig. 1), the weevil reaching Louisiana in 1903 and crossing into Mississippi in 1907. When the Mississippi River failed to halt the advance of the boll weevil, it was realized that all the eastern part of the Cotton Belt would soon become infested. In 1916 the boll weevil reached the Atlantic seaboard in Georgia and by 1922 (31 years after crossing the Rio Grande from Mexico) had become established nearly to the northern limits of cotton production and in more than 600,000 square miles of the Cotton Belt. Its advance was largely by flight and local movement of unginned cotton and cotton seed to and from the public gins, and there are but few authentic records of isolated establishment ahead of the general line of spread. In the late summer boll weevils for unknown reasons take to the air and disperse in all directions. This migration by repeated short flights enabled the boll weevil to move forward from 60 to 160 miles per season. Although several States and the Federal Government had quarantines and regulations to prevent spread through the movement of infested cotton products, it is remarkable that the boll weevil moved across the Cotton Belt mainly under its own power. That spread with infested cotton or seed can occur is shown by the accidental establishment of the boll weevil in Haiti in 1932.

Careful surveys made each fall by Federal and State entomologists to determine the new areas infested furnish a complete record of the progress across the Cotton South (fig. 1). The more rapid and extensive spread toward the east and north than to the west is due to the hot, dry climate from the western third of Texas and Oklahoma westward and the cold winters of the extreme northern edge of the Cotton Belt.

PANIC FOLLOWED THE BOLL WEEVIL

As the boll weevil moved in its relentless march across the Cotton Belt, the damage it caused threatened to ruin the cotton industry. To

appreciate the chaos caused by the weevil, it must be remembered that southern agriculture and industry depended almost entirely on the

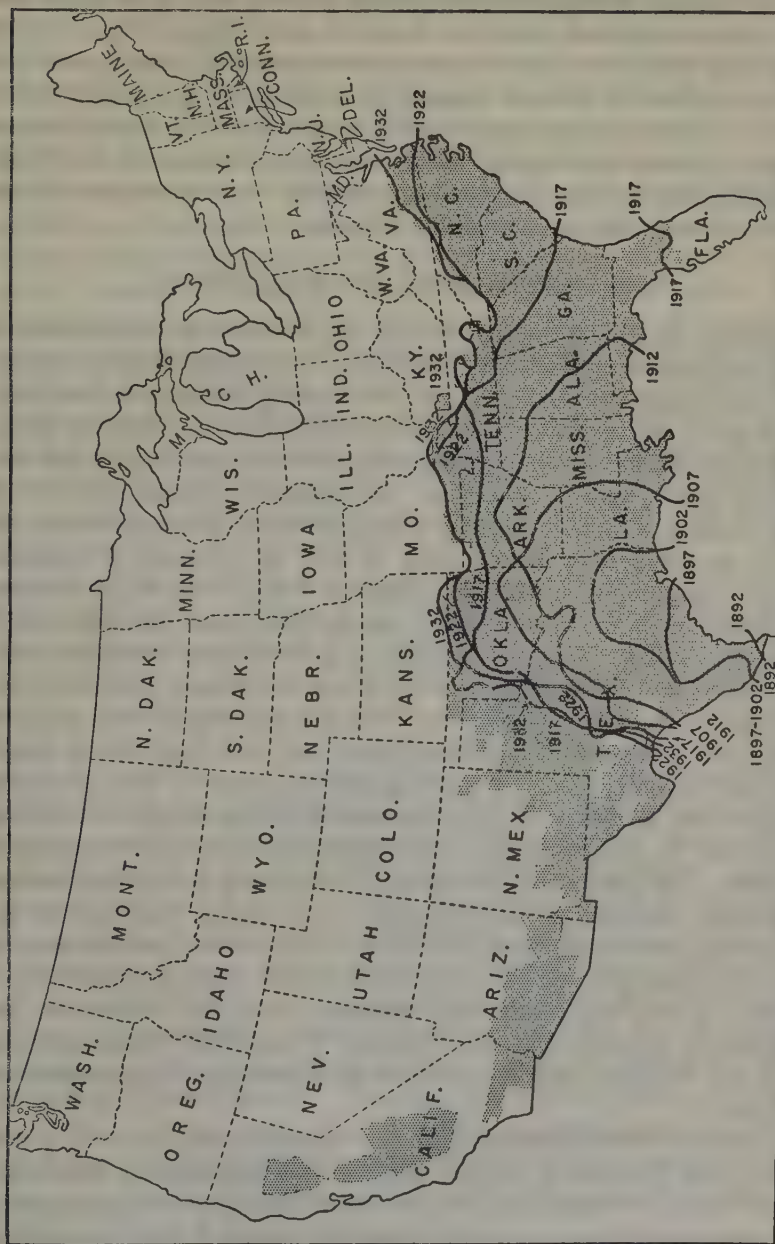


FIGURE 1.—Spread of the boll weevil, and cotton-producing area of the United States.

one crop—cotton—and that losses of from one-third to one-half of the yield occurred for the first few years in each newly invaded area.

Farmers, merchants, and bankers were bankrupted; farms and homes in whole communities were deserted; labor and tenants were demoralized and moved to other sections; and a general feeling of panic and fear followed the boll weevil as it moved into locality after locality. It became the theme of numerous verses and folk songs, and the "Ballad of the Boll Weevil" as sung by the Texas Negroes in the nineties was the basis of the early "blue" songs. The boll weevil became known, by name and reputation at least, to every man on the street and affected every home—something tangible that was responsible for crop failures as well as their other troubles.

THE FIGHT AGAINST THE BOLL WEEVIL

Research to reduce the losses from the boll weevil was started by the then Division of Entomology in 1894 shortly after the first infestation was reported in Texas and has continued to the present time, with only a short interruption from 1898 to 1900, when the State of Texas made a special boll weevil appropriation and all work on this pest was handled by the State entomologist. As other States became threatened with invasion, Congress made a special boll-weevil appropriation to enable the Bureau of Entomology in 1901 to discover, if possible, means of preventing spread into adjacent States. Dr. W. D. Hunter was placed in charge of the work, a post he filled with distinction until his death in 1925. Many entomologists later became associated with the Federal and State investigations of the boll weevil, and their contributions to various phases of the work are too numerous to mention individually. The work was enlarged in 1902 and a laboratory established at Victoria, Tex. In 1904 the appropriation of \$250,000 made to enable the Secretary of Agriculture to fight the ravages of the boll weevil was the largest amount ever appropriated for any insect up to that time. The Bureau of Entomology had already found that changes in cultural practices of cotton reduce weevil losses, and part of the money was made available to the Bureau of Plant Industry to demonstrate to cotton growers how to produce cotton under boll-weevil conditions. These large-scale demonstrations were so valuable to the cooperating growers that the Farmers' Cooperative Demonstration Work has developed into what is now the Federal and State extension services.

As the boll weevil spread into new territory, the laboratory was moved from Victoria to Dallas, Tex., in 1905 and another laboratory established at Tallulah, La., in 1909. Since that time field laboratories have been established at various strategic places in the Cotton Belt to study local features of the boll-weevil problems. New problems are still constantly arising.

Early investigations showed that the crude insecticides and methods of application then available would not control the boll weevil and that earliness of maturity offered the best hope of evading damage by producing a crop of cotton before the weevils became abundant late in the season. Special attention was devoted to improving cultural practices and varieties of cotton. Changes along these lines were based on sound agronomic principles and are now generally used by growers, often without the conscious realization of their value in weevil control. After 20 years of continuous effort, an effective insecticidal control was developed and by the combined use of these direct and indirect methods of control every grower can prevent excessive weevil losses. Numerous mechanical devices, concoctions, and secret remedies have been proposed by people from all walks of life, many of whom had never seen a boll weevil, and growers spent millions of dollars on these worthless methods. The State of Texas offered a \$50,000 prize for an efficient remedy for the boll weevil and a great deal of time was spent by research workers testing the numerous compounds offered without finding any of real value. The numerous "boll-weevil conventions" held throughout the south are another unique chapter in boll-weevil history.

The boll weevil during the past 50 years has affected the agriculture and economics of the South in so many ways that only a few phases can be discussed. Among other things, the boll weevil helped in the diversification of crops and production of livestock. So despite the hardships caused by the boll weevil and the toll still taken from the cotton growers, some benefits have occurred, and in recognition of this fact the citizens of Coffee County, Ala., erected a monument on the town square of Enterprise, "In profound appreciation of the boll weevil and what it has done as the herald of prosperity" (pl. 1, fig. 2).

The literature on the boll weevil has become voluminous. Some of the early publications of the United States Department of Agriculture were in Spanish, German and French for the different nationalities of American cotton growers. The many bulletins, circulars, and posters of the Department of Agriculture, State experiment stations, and extension services of the infested States and the innumerable articles and cartoons in newspapers have made the boll weevil one of the most publicized insects. The contributions to the development and use of control methods for the boll weevil by many State and Federal entomologists, agronomists, cotton breeders, extension workers, and others provide an excellent example of the value of cooperative and continued research on a complex problem.

LIFE HISTORY OF THE WEEVIL AND NATURE OF ITS DAMAGE

The cotton square or unopened floral bud is the principal food of both adults and larvae of the boll weevil, though bolls are also severely

damaged and the adults occasionally feed on the tender foliage. The sharp mandibles on the tip of the snout are used to puncture or drill through the unfolded corolla of the squares and the carpel walls of the bolls for feeding and egg laying (pl. 2, figs. 1 and 2). The feeding punctures are usually larger and deeper than those for oviposition, but both produce sufficient injury to make the bracts "flare" or open up, the square to turn yellow, and usually shed or fall from the plant, resulting in the loss of a potential boll of cotton. Weevils prefer small bolls with tender carpel walls, though bolls of upland cotton are not safe from weevils until 20 to 30 days old and those of sea island cotton are attacked until they mature and open. The pearly-white eggs are placed deeply within the cavities in squares or bolls and are difficult to find, but the egg punctures are sealed over with a gummy secretion that enables a careful observer to distinguish them from feeding punctures. The eggs hatch in 3 or 4 days into white, wrinkled grubs about $\frac{1}{25}$ inch in length. After feeding from 7 to 12 days, depending on the temperature, the larvae pupate within the square or boll in which they develop. The pupal stage lasts for 3 to 5 days, the adults cut their way out, and are ready to lay eggs after feeding for 3 or 4 days. Thus with an average life cycle of 20 to 30 days, a laying capacity of 100 to 300 eggs per female, and 3 to 7 generations per season, an enormous population of weevils develops by fall. Small bolls are shed in the same way as the squares, but large bolls remain on the plants. The lock or carpel of the boll in which a larva feeds fails to develop properly, the lint is cut, stained brown, and is partially or completely ruined. When several larvae develop within a boll, as often occurs when food is scarce, the entire boll may be ruined (pl. 3, fig. 1). The winter is passed in the adult stage, largely under weeds or woods trash within or near the cotton fields, in haystacks, spanish moss, or any place that affords protection from the cold (pl. 3, fig. 2). However, some adults overwinter within the pupal cells in old bolls, especially in the drier areas of the Southwest. Weevils require a longer period to develop in bolls than in squares, but the adults are more robust and better adapted to survive the winter than those developing in squares.

The fact that cotton is the principal host plant of the boll weevil simplifies control. Adults will feed occasionally on okra and other plants of the same family as cotton (Malvaceae), but the only records of breeding in plants other than cotton are from althea (*Hibiscus syriacus*) and the so-called Arizona wild cotton (*Gossypium thurberi*). A few weevils have been reared from the seed pods of althea growing in weevil-infested cotton fields, but *Thurberia* is readily infested. Althea is an ornamental shrub extensively grown in the south and a potential host if boll-weevil eradication should be undertaken by noncotton zones (Journ. Econ. Ent., vol. 27, No.

4, August 1934). *Thurberia* occurs in the United States only in the mountains of southern Arizona and New Mexico, where it is too hot and dry for the boll weevil to become established. However, a variety of the boll weevil more resistant to arid conditions, known as the *Thurberia* weevil (*Anthonomus grandis thurberiae* Pierce), is well established in *Thurberia* in central Mexico and Arizona and in cotton on the west coast of Mexico. The *Thurberia* weevil probably reached the United States long before the boll weevil, but no cotton was grown in the area and it was of no importance at the time. Cotton production extended westward to escape boll-weevil damage, and the *Thurberia* weevil transferred to cotton when planted near its habitat. The first *Thurberia* weevils were found in fields near Tucson, Ariz., in 1920. It differs from the boll weevil in having only one generation a year on *Thurberia* and in the adults' passing the winter only within the dry seed pods of *Thurberia* or bolls of cotton. Although the *Thurberia* weevil readily attacks cotton and develops two or more generations a year, it does not become abundant enough to cause serious damage to cotton grown under irrigation. The habit of the adults' remaining within the pupal cells until emergence is stimulated by moisture has become so thoroughly fixed that it was not changed by experimentally maintaining *Thurberia* weevil on cotton for 10 years, and at the end of the experiment an irrigation of the field for planting cotton caused all the adults to emerge and perish before squares became available for food. Carefully controlled biological tests have shown that the *Thurberia* weevil will interbreed with the boll weevil, and it is feared that if it should become established where the boll weevil occurs, a more vigorous hybrid strain of cotton-feeding weevil might result. The natural climatic barriers have prevented the boll weevil from moving westward and a quarantine requiring treatment of cotton moved from the *Thurberia* weevil area has maintained the gap between the two insects.

CULTURAL METHODS

Changes in cultural methods that hasten early maturity of the crop were developed and adapted rapidly after establishment of the boll weevil in south Texas. One of the recommendations of the first entomologist to investigate the boll weevil—the early destruction of the cotton stalks—has been proved by later research to be biologically sound. Early fall destruction of the stalks removes the food from weevils, stops the late season breeding and build-up in numbers, and causes the adults already present to enter hibernation in a semistarved condition that increases the winter mortality. That the earlier the stalks are cut the more effective this method of control

has been proved by placing weevils in hibernation cages at different dates to simulate depriving them of food under field conditions. In a long series of experiments at Tallulah, La., no survival occurred when weevils were installed in cages during the first week in September, while the highest survival (2.55 to 2.92 percent) was from installations during the last half of October and first half of November, the period when the frost normally kills cotton and weevils enter hibernation under natural conditions (U. S. Dep. Agr. Techn. Bull. 486).

Numerous agronomic practices, such as thorough preparation of the seed bed, the use of commercial fertilizers, early planting, frequent and thorough cultivation, that stimulate rapid growth and maturity are of great value in evading damage. Perhaps no recommendation aroused more controversy than early planting, because many people believed that late planting would permit the overwintered weevils to emerge from hibernation and die before squares became available for food. Numerous experiments and actual farm experience have definitely proved the fallacy of this reasoning, and planting as early as the danger of frost has passed is now almost universally practiced. An outstanding contribution by agronomists was the discovery that delaying thinning until the plants were several inches tall and leaving the plants thick in the drill suppressed the formation of vegetative branches and stimulated early fruiting. These modifications in cultural practices and changes to new varieties have changed the early fields of from 5,000 to 6,000 large, heavily branched cotton plants per acre that fruited until late in the season to 10,000 to 15,000 smaller and more upright plants that produce fewer bolls per plant but more bolls per acre in a much shorter time. Many of these improvements in cultural methods and increase in yield would have occurred in the normal course of events, but the aid given cotton growers in fighting the boll weevil has done much to overcome the traditional slowness of the South in adopting changes.

EFFECT OF BOLL WEEVILS ON COTTON VARIETIES

The types and varieties of cotton grown in the boll-weevil infested areas have undergone material changes which have aided more in reducing weevil damage than is generally realized. The first changes in varieties to meet weevil conditions increased the production of short-staple, inferior cotton which became difficult to market. This surplus of low-grade cotton still plagues the industry, and the lack of markets has stimulated the development of improved varieties with better staple. Cotton is a perennial but has grown under cultivation for centuries as an annual. The plant has the peculiar habit of producing squares and bolls in successive zones, as the fruiting branches form on

the main stem and vegetative branches. Fruiting of wild cotton normally continues during the rainy season and throughout the growing season on cultivated cotton so that bolls are present in various stages of development from those newly formed to those reaching maturity in 45 to 60 days. Cotton is also very prolific in fruiting and normally produces about three times as many squares as the plant can support. If adverse conditions, such as boll-weevil damage, cause excessive shedding and prevent the setting of a normal crop of bolls, plants persist in their efforts to produce the seed-bearing bolls until killed by frost and thus provide food for the boll weevil over a longer period. Prior to the advent of the boll weevil there was sufficient time in the southern part of the belt to permit the cotton plant to grow large in size and mature bolls on the later branches. It soon became evident that late bolls were totally ruined, and producing a crop became a race against the boll weevil. The better varieties of medium- and long-staple cotton grown at the time of the weevil invasion were large, vigorous-growing productive plants but late in maturity, and these were rapidly replaced by the short-staple varieties of inferior quality grown in the shorter seasons in the northern part of the belt that offered the one advantage of early maturity. Many of the famous old varieties passed out of existence and many of the so-called varieties that were brought in were sold under a multitude of names and added to the confusion.

The 131 cotton varieties listed as grown in the United States in 1896 (U. S. Dep. Agr., Office of Exp. Stat. Bull. 33) increased to 608 so-called varieties in 1910 (U. S. Dep. Agr., Bur. Plant Ind. Bull. 163) and in addition some 35 other varieties had come and gone in the 14 years. According to C. B. Doyle, of the Bureau of Plant Industry, Soils, and Agricultural Engineering (unpublished manuscript), only 10 of the 608 varieties listed in 1910 were extensively cultivated in 1942, and many of the 700 newer varieties appearing since 1910 are no longer being grown.

A desirable variety of cotton for growing under boll-weevil conditions should be early maturing, of determinate growth that sets and matures its crop quickly with little or no late fruiting, productive, and with high-quality, uniform lint. Combining these characteristics is difficult, but geneticists have aided in evading weevil damage by developing varieties that set a full crop and mature the bolls in a much shorter period than those formerly grown. A fairly large number of varieties will always be needed to produce the various types of lint required for the numerous needs which cotton fulfills and that are adapted to the diversified climatic and soil conditions of the 19 cotton-producing States. Varieties are becoming better and fewer in number, and in 1942 over 6 million acres, or about one-third of the total acreage, was planted to 64 varieties in one-variety communities.

In discussing the progress made in developing improved varieties after the coming of the boll weevil, Ware states in the 1936 United States Department of Agriculture Yearbook,

Considerable impetus was given to cotton breeding about this time, largely through the discovery that many of the early-maturing cottons were of inferior quality and that their production was resulting in the loss of special markets which had been using the better cottons of pre-boll weevil days for many years. . . . The greatest improvement has taken place in the medium staples, $1\frac{5}{16}$ to $1\frac{1}{16}$ inches, inclusive. In 1928, only 39 percent (of the United States crop) was of these lengths, whereas in 1935 this had increased to 50 percent of the crop. On the whole there has been an increase in the average staple length of the entire crop of approximately $\frac{1}{32}$ inch.

The time required for setting and maturing a crop of bolls has been so shortened that it is approaching the practical limitations to which it can be carried, and more attention is now being given to varietal resistance to boll-weevil attack. None of the numerous species, varieties, or strains of cotton has been found immune to boll weevils. Attempts have been made at various times to discover a resistant cotton in the native home of the boll weevil, and studies have been made of some of the characters which contribute to resistance, but this important problem has not received the attention it deserves. Among other plant characters that have been studied in their relation to weevil damage are the shedding of the infested squares and small bolls, proliferation, pilosity, thickness of boll walls, and toughness of carpel lining. The mortality of immature weevils in shed forms is considerably higher than in those hanging on the plant owing to exposure to higher temperatures and attack by ants and other predators on the soil surface. The effectiveness of heat in killing the grubs is greatly reduced by shading of the plants late in the season or by abundant moisture, but the mortality often reaches 50 percent after 3 or 4 days' exposure to 95° F. or above. Small plants with few lateral branches and "open" foliage afford less shade and are desirable characteristics of some varieties. Proliferation, or the development of numerous elementary cells in the square and boll, was observed as early as 1902 (U. S. Dep. Agr., Bur. Ent. Bull. 59) to kill from 10 to 15 percent of the developing weevil forms by mechanical crushing, but it seems to be present to about the same extent in all upland varieties. Pilosity of stalks and leaves varies greatly among varieties from almost glabrous sea island varieties to 300 to 400 hairs per square centimeter in some upland cottons but has not been found to hinder the movement of adult weevils over the plant as previously supposed. However, pilose leaves cause better adherence of calcium arsenate, especially when applied to dry cotton, and thus indirectly aids weevil control to some extent. The thickness of the boll walls and toughness of the

carpel lining offer some resistance to weevil puncture, but no varieties have been found with bolls that weevils cannot pierce.

DEVELOPMENT OF INSECTICIDAL CONTROL

The insecticides and methods of application available to entomologists 50 years ago were very limited. Most of the insecticides then in use were applied as sprays with crude machinery and gave poor or no weevil control. Early tests showed that paris green, which had recently come into use, killed some of the adults, but the control was not sufficient to materially increase yields. Lead arsenate in paste form was later found to kill some of the weevils but could be applied only as a spray, which was not very practicable for cotton. Various other materials were likewise found of little value, and for 20 years the search for an effective insecticide for the boll weevil was unsuccessful. In 1908 Wilmon Newell, entomologist of the Louisiana Crop Commission, stimulated new interest in insecticidal control by introducing lead arsenate in powder form for dusting cotton for boll-weevil control. This dust gave better weevil control than any material previously tested, but the results were erratic and it was never extensively used. However, his work was responsible for the development and later extensive use of insecticides in dust form for many insects. The next important step in insecticidal control of weevils came in 1916, when B. R. Coad, of the Bureau of Entomology, found that keeping the cotton plants thoroughly covered with an arsenical dust throughout the growing season would kill adult weevils and that calcium arsenate was the most effective of the many materials tested. Calcium arsenate was then a new material that had been tested in a limited way for fruit and shade-tree insects but was not available in commercial quantities. Extensive experiments were started to improve its chemical and physical properties and methods of application for weevil control. In the 1917 experiments the increase in yields from fields dusted with calcium arsenate were so outstanding that in 1918, 35,000 acres of cotton were dusted under Bureau of Entomology supervision. Specifications were developed and manufacturers were aided in making calcium arsenate to meet the rapidly increasing demands. Much of the early calcium arsenate was of poor dusting quality and caused serious burning of the plants, and much effort was expended by the Bureau and State experiment stations during the following years in overcoming these defects. Grower response was immediate, and over 3 million pounds of calcium arsenate were used for weevil control in 1919, 10 million pounds in 1920, and 60 to 70 million pounds have been manufactured annually during recent years.

Entomologists were stationed at strategic points in the weevil-infested areas to conduct demonstrations in cooperation with State and Federal extension workers to teach growers the principles of weevil control. The discovery of the effectiveness of calcium arsenate against the weevil came shortly after World War I, when the weevil had spread over most of the belt, damage was at its maximum, and cotton was selling at a high price. The immediate problem was not to interest growers in using calcium arsenate but in using it correctly.

Since the boll-weevil grubs feed entirely within the squares and bolls and cannot be reached by poisons, control is directed against the adults. They too feed externally only slightly, and it is more difficult for them to obtain a lethal dose than the foliage-feeding insects. Adults supplied with water were found to live longer than those without water, and it was assumed at first that adults were killed entirely by drinking poisoned water. Later studies showed that weevils could be killed by crawling over dry surfaces dusted with calcium arsenate because they continually touch the tips of their snouts to the surface and sufficient quantities of the tiny dust particles adhere to the moist mandibles to cause death. Ordinary sprays are deposited in larger particles which adhere more closely than dusts and have never given as good control. The method by which weevils obtain a lethal dose of poison and the fruiting habits of the cotton plant indicate that the entire plant must be kept thoroughly covered with calcium arsenate dust. As cotton produces more blooms than the plant can carry to maturity, it is not necessary to begin dusting until the weevils cause more shedding than would normally occur. The danger point, when dusting should begin, was first placed at 10 to 15 percent of the squares punctured for feeding or oviposition but later raised to 20 to 25 percent for cotton growing in fertile soil. The infestation usually varies from field to field, but the punctured squares are easily seen, and counting 100 or more squares per field at frequent intervals provides a reliable index of weevil abundance and the need for control. From 4 to 6 applications of 5 to 8 pounds of calcium arsenate dust per acre at 5-day intervals are usually sufficient to bring the weevils under control and produce a full crop, though one or more later applications for boll protection may be needed when infestations are heavy. At first it was thought necessary to dust with calcium arsenate when the plants were wet with dew, but later experiments showing that effective applications may be made at any time of day when the air is calm have reduced the drudgery of night dusting. Many other improvements and adaptations to varying local conditions have been gained from continued experimentation, but the basic principle of keeping the plant thoroughly covered during the critical fruiting period or until the weevils are brought under control remains unchanged. The improved varieties of determinate

growth that set a crop of bolls in a shorter period have helped reduce the time that protection is needed. Calcium arsenate does not kill all the weevils on the plants, nor is that necessary; it only affords sufficient protection to maintain a favorable balance between the production and shedding of squares so that a normal crop can be produced.

Another method of application of calcium arsenate that has been used in the Southeastern States is to smear the upper leaves of the small plants before squares are formed with a mixture of calcium arsenate, molasses, and water by means of a homemade rag mop, or "mopping" as it is called. The presquare applications of sweetened poison kill some of the overwintered weevils but the weakness of this method is that a large percentage of the early emerging weevils die naturally before squares are available for food and approximately one-third of the total weevils always emerge from hibernation after squares are large enough for oviposition and the molasses mixture is no longer effective. A large series of experiments at many localities has shown that sufficient weevils emerge late enough to cause serious loss when conditions are favorable for weevil multiplication and that presquare applications alone cannot be depended upon for control.

Continued search for new insecticides has shown that calcium arsenate is still the most effective of the hundreds of materials tested against the boll weevil, including the recently discovered and much publicized DDT. It has a number of disadvantages as well as advantages. It is the cheapest of all the arsenical insecticides, has good dusting qualities, and the commercial calcium arsenate now available seldom injures the cotton plants. However, it does cause injury to the germination and growth of some crops, particularly legumes, on certain light, sandy soils of the Southeastern States when used in large dosages or over a period of years for boll-weevil control. It also destroys the natural enemies and causes an increase of the cotton aphid following several applications for control of other insects. In some cases the losses caused by the build-up of aphids largely offset the gains from weevil control, though in recent years it has been found practicable to overcome this by adding nicotine or derris to the calcium arsenate dust. The proper use of calcium arsenate for weevil control often means the difference between a profit and a loss in cotton production. Field plots at Tallulah dusted with calcium arsenate for weevil control annually during the past 25 years averaged 300 pounds of seed cotton per acre, or 30 percent increase in yield, and at Florence, S. C., the 12-year average gains have been 283 pounds. Similar results have been obtained at numerous other localities, with gains of from one-half to a bale of cotton per acre not uncommon where heavy weevil infestation occur on cotton growing on productive soil. It is generally not economical to spend from \$3 to \$5 per acre per season for weevil con-

trol on cotton having a potential yield of less than one-third bale per acre if no weevils were present or where the expected gains are less than 100 pounds of seed cotton per acre. Unfortunately there is a large acreage of cotton in this category, though the restriction on acreages during recent years has tended to reduce the use of low-production land for cotton.

While no exact data are available on the amount of calcium arsenate used for weevil control, a large proportion of the calcium arsenate manufactured is used on cotton, and it is estimated that the 2 million acres or more dusted annually for boll-weevil control increases the growers' profit by many times the total of \$3,500,000 spent by the United States Department of Agriculture on boll-weevil research since the work was started in 1894. Despite the benefits derived from the use of calcium arsenate, it is not the perfect insecticide for boll-weevil control. An inexpensive material is needed that is more toxic as a stomach poison or that will kill boll weevils by contact and not cause an increase in aphids or injury to soil.

DEVELOPMENT OF DUSTING MACHINERY

Coincident with the rapid expansion in the use of calcium arsenate, it was necessary to develop methods of application. No suitable dusting machines were available, and assistance was given manufacturers in improving the efficiency of the existing models and testing new models at the Tallulah laboratory. The possibility of using airplanes for cotton-insect control was suggested by the work of the Ohio Experiment Station in distributing lead arsenate against the catalpa sphinx in 1921. The first airplane tests against cotton insects were made in the fall of 1922 through the cooperation of the Air Service of the United States Army in furnishing planes and personnel (Dep. Agr. Bull. 1204). In the first flights calcium arsenate was dropped by hand from the planes for control of the cotton leafworm, but it soon became evident that it would be necessary to develop methods of distributing insecticides evenly and at controlled rates. Research by the Bureau of Entomology in cooperation with the then Bureau of Agricultural Engineering during the next few years developed specifications for hoppers and distributing apparatus that would effectively dust a 50- to 75-foot swath for weevil control (pl. 4, figs. 1 and 2). The use of airplanes for weevil control and later for other cotton insects rapidly expanded and soon became an important factor on the larger plantations. Dusting by airplanes is more rapid than from the ground, as one plane can cover from 750 to 1,000 acres a day, an important factor when it is too wet to use ground machinery or when large acreages are to be covered quickly. Most of the airplane dusting is done by commercial operators by contract per pound of insecticide or

per acre dusted. The cost usually ranges from 25 to 75 cents per acre-application and compares very favorably with ground applications. At present a number of commercial companies maintain an estimated 200 planes equipped for crop dusting at the instant call of growers, and some of the larger commercial dusters have entomologists with each dusting unit who make infestation records and advise growers when to dust. The use of airplanes for boll-weevil control was the basis for the later developments and use for control of mosquitoes and of various insects attacking commercial vegetable crops, orchards, and forests, as well as for spreading grasshopper poison bait, seeding rice and cover crops, application of fertilizers, chemical defoliation of cotton, and other agricultural uses. A more recent development is the use of concentrated sprays whereby 1 to 3 gallons of concentrate can be finely atomized from a plane to cover an acre of forest or crop land. Airplane spraying has been successfully used in freeing large areas of disease-carrying mosquitoes and other insects and for forest- and crop-pest control. Application of insecticides by airplanes is spectacular but at the same time entirely practical, economical, effective, and the most convenient method ever devised for treating large acreages.

For the smaller growers the entomologists and engineers have worked with manufacturers in developing ground machinery of various types, prices, and capacities for dusting any size acreage at 4- or 5-day intervals (pl. 8). The rotary-type hand gun (pl. 5, fig. 1) will take care of the dusting of 8 acres of cotton; the saddle gun, 40 to 50 acres; the two-nozzle traction machine (pl. 5, fig. 2), 40 to 60 acres; the four-nozzle traction power cart machine, 75 to 150 acres; the power-operated multiple nozzle cart machine (pl. 6, fig. 2), 200 to 300 acres; and the tractor-operated machines with five to eight nozzles (pl. 7), still larger acreages (U. S. Dep. Agr. Farmers' Bull. 1729).

LOSSES CAUSED BY WEEVILS

As is usual with insects introduced into a new environment, the losses caused by the boll weevil were more severe during the first years while the insects were becoming stabilized and control measures developed. Estimates of the damage have been made by the Bureau of Agricultural Economics each year since 1909, based on the reports of thousands of volunteer farmer crop reporters and are probably the most accurate records available for any insect. The losses show a general increase as the weevil spread across the Cotton Belt, reaching a maximum of over 30-percent reduction from full yield for the United States in 1921 (fig. 2). Since that time the cyclic peaks of the damage curve have been lower and the general trend has been downward, especially in recent years. However, in spite of the progress that has been made

in control, the boll weevil is still taking an enormous toll of about one bale of every seven produced. This annual loss of over a million and a half bales of cotton, together with the seed, is valued at some \$200,000,000 at average farm prices. Since the boll weevil causes more damage in the United States than in any other country, the American grower is at a disadvantage in a highly competitive world market. It is not feasible of course to prevent all this loss to a low-value-per-acre crop like cotton, but it is estimated that more than half of the losses now caused by the weevil can be economically prevented by the more general use of control measures.

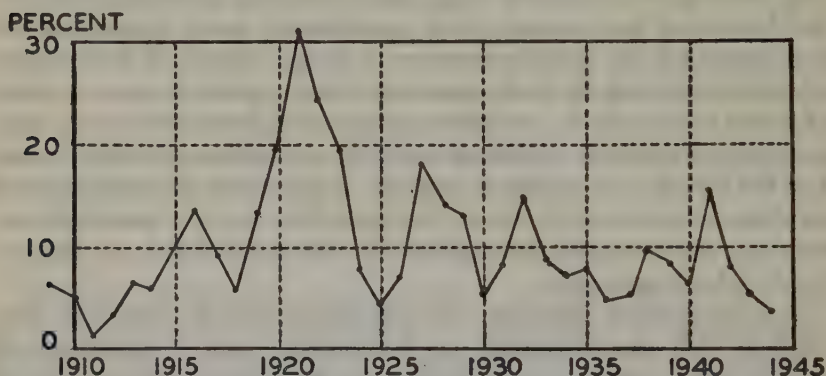


FIGURE 2.—Boll-weevil damage 1909–1945. Percent reduction from full yields as reported by crop correspondents.

The weevil damage is most severe in southern and eastern Texas, Louisiana, and the central parts of Mississippi, Alabama, and Georgia where the winters are comparatively mild, the rainfall abundant, and there are large areas of favorable hibernation quarters. The winters in the northern part of the belt usually kill sufficient hibernating weevils to hold the damage down, so that little insecticidal control is needed. Part of the extreme southern areas where the soils are of low production capacity have found it more profitable to change to other crops than to compete with the boll weevil. The present acreage planted to cotton in Florida is less than 10 percent of the pre-boll-weevil acreage. Sea island cotton is the finest quality of cotton and was a profitable industry in Florida and the coastal plains of Georgia and South Carolina before the boll-weevil invasion. It fruits over a long period, the bolls are soft, and subject to weevil attack until they open. Production has practically ceased, owing largely to weevil damage. Weevil damage is partly responsible for the expansion of cotton production in west Texas and Oklahoma, where the hot, arid climate prevents the weevil from becoming abundant, and in the irrigated sections of New Mexico, Arizona, and California, where the boll weevil has never become established. There is evidence that the boll

weevil is becoming better acclimated to adverse climatic conditions, though the extent to which this occurs is obscured by animal rein-festation of the border areas by migrating weevils.

FACTORS INFLUENCING WEEVIL DAMAGE AND USE OF CALCIUM ARSENATE

The great variation in damage from year to year and from region to region depends largely on the number of weevils entering hibernation in the fall, the winter survival, and weather conditions during the growing seasons. Fortunately a large percentage of the weevils fails to survive the winter, for with such a high rate of reproduction it would be unprofitable to raise cotton in much of the infested area. Survival in cages (pl. 9, fig. 1) simulating natural conditions seldom exceeds 10 to 15 percent under most favorable conditions; the 15-year average at Tallulah, La., was only 1.22 percent in an area where weevil damage is high. Spring emergence from hibernation begins when the daily mean temperature reaches about 60° F., or about the same time cotton begins growth, and continues for 2 or 3 months, so that some of the weevils are certain to find squares available for oviposition. Hot, dry weather during the summer kills large numbers of weevil larvae and pupae, while cool, wet weather during June, July, and August is favorable for multiplication so that a heavy survival does not necessarily result in heavy damage, or vice versa. Nevertheless information on the relative number of weevils surviving the winter from year to year helps growers in planning control and manufacturers in supplying the insecticides that may be needed. Information on the numbers entering hibernation is obtained by fall examinations of trash and spanish moss from woods adjacent to cotton fields, and on the survival by spring examinations in the same vicinities. This information is supplemented by determining survival of weevils in hibernation cages in different sections of the Cotton Belt and the overwintered weevils that appear on small plants in the spring. During the war growers and others have also been furnished current weekly information on the seasonal weevil infestation obtained by a survey of insect abundance conducted cooperatively by State and Federal agencies.

Many of the more successful growers use calcium arsenate as a regular part of cotton production, but much educational work is needed in acquainting more growers with the value of weevil control and when and how to apply insecticides most effectively. Nearly half of the total cotton is produced by small growers who average less than 10 bales per farm. They often lack the necessary finances for dusting machinery and insecticides. The variation in weevil

damage from year to year always arouses the hope that this will be a light weevil year and a crop can be made without dusting. Other growers have used calcium arsenate improperly or used it when not needed and failed to make a profit. Also before the acreage-adjustment program was inaugurated it was a common practice to plant extra acres of cotton for the boll weevil and to harvest what the weevils left. The use of calcium arsenate also increases with the price of cotton. In 1931, when farmers received about 6 cents per pound for cotton, the production of calcium arsenate in the United States was 26 million pounds, while in 1942, when cotton sold for about 19 cents per pound, the production of calcium arsenate increased to 68 million pounds. The average yield for the United States was 211 pounds of lint per acre in 1931 and 272 pounds of lint per acre in 1942.

The cotton-insect survey conducted during the past 3 years furnished the most complete picture of current weevil conditions that has ever been obtained. About 25,000 infestation records were obtained each season through the cooperation of volunteer farmer crop reporters, 4-H Club members, vocational agriculture teachers and students, county agents, Federal and State entomologists, and others. This information was tabulated and interpreted by experienced entomologists at weekly intervals as an aid to State and extension entomologists in advising growers of the need for weevil control and industry in distributing insecticides to the areas where most needed. Besides furnishing information on the current need for weevil control at the time when damage could be prevented, the survey was of permanent educational value in teaching farmers and future farmers to recognize damage and the value of control. The 4-H Clubs have added insect reporting to their list of projects for which credit and certificates are awarded to participating members.

RECENT TRENDS IN WEEVIL CONTROL

After 50 years of boll-weevil damage, cotton continues to be the most important cash crop in the South and is the most important source of income for 11½ million farm families and hundreds of thousands of others employed in the ginning, marketing, manufacturing, and distribution of cotton and cotton products. The American cotton industry is now facing serious competition from increasing production of foreign cotton and increased use of synthetic fibers. It is generally recognized that the future depends on decreasing the cost of production and improving the quality of cotton. Both of these objectives can be aided by better insect control (pl. 9, fig. 2; pl. 10, fig. 1) and the State and Federal programs are being reorganized to emphasize insect and

disease control as one of the major needs in the more economical production of cotton.

The importance of early fall destruction of cotton stalks in reducing the fall build-up of weevils has been recognized but not as generally used as it should be because of the difficulties in getting cotton picked before frost. The recent development of chemical defoliation of cotton plants may overcome this obstacle and have far-reaching effects on boll-weevil control. Dusting with 20 to 30 pounds of calcium cyanamide per acre causes the leaves, squares, and small bolls to wither and fall from the plants (pl. 10, fig. 2) and the large bolls to open normally within 3 or 4 days just as a frost does. The removal of the leaves reduces the trash adhering to the lint, improves mechanically harvested cotton by a full grade, increases the amount that can be picked by hand or mechanically, and permits the harvesting of the entire crop at one operation instead of the two or three pickings formerly required to avoid weather damage to lint. Picking by hand represents one-third of the cost of cotton production, and chemical defoliation removes one of the greatest difficulties in the development and successful use of mechanical cotton pickers. Calcium cyanamide is a nitrogenous fertilizer and is beneficial to the soil. Its use as a chemical defoliant expanded rapidly during the wartime labor shortage and has already swept across the belt from South Carolina to California. The favorable response to chemical defoliants has started research for other materials to meet the increasing demand.

The numerous inquiries from returning World War II pilots indicate a great expansion in the use of airplanes for pest control. In the past the planes used for dusting have been converted small passenger models, but with the recent advances in aeronautical engineering, specially designed aircraft with greater carrying capacity, maneuverability, safety and other features better adapted for pest control than those now in use may be expected. Improvements in ground equipment such as the recent tractor-attachment dusters are keeping pace with the increased trend of mechanization of cotton culture and reducing the cost of equipment and labor for weevil control. The new methods of applying insecticides in the form of liquefied gas or thermal aerosols and concentrated sprays are additional weapons for testing against the boll weevil.

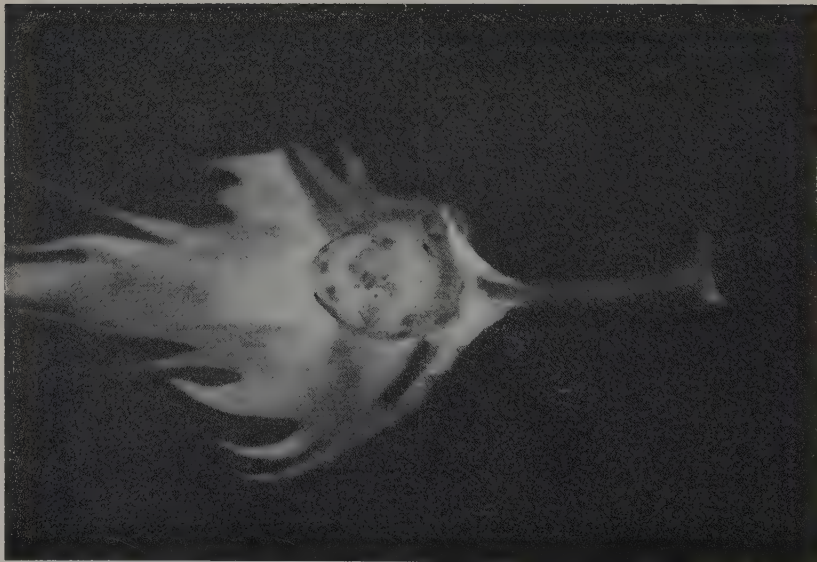
The recent progress in developing many new materials for insect control has stimulated renewed research for a better insecticide than calcium arsenate for the boll weevil. DDT is not the answer for the boll weevil, but if further experimentation confirms the preliminary results, some of the new synthetic insecticides such as benzene hexachloride may be the beginning of a new era in boll-weevil control.



1. ADULT BOLL WEEVIL (ENLARGED).



2. MONUMENT TO THE BOLL WEEVIL, ENTERPRISE, ALA.
(Photograph from Alabama Polytechnic Institute, Auburn, Ala.)



1. DAMAGED COTTON SQUARE SHOWING EGG AND FEEDING PUNCTURES.



2. BOLL WEEVIL ENLARGED) FEEDING ON COTTON BOLL.



1. BOLL COMPLETELY DESTROYED BY LARVAE.



2. WEEDS AND WOODS ADJACENT TO COTTON FIELDS PROVIDE FAVORABLE HIBERNATION FOR WEEVILS.



1. AIRPLANE DUSTING COTTON FOR BOLL-WEEVIL CONTROL.



2. FILLING THE HOPPER OF AN AIRPLANE WITH CALCIUM ARSENATE.

Planes carry from 300 to 500 pounds of insecticide.



1. HAND DUSTERS.



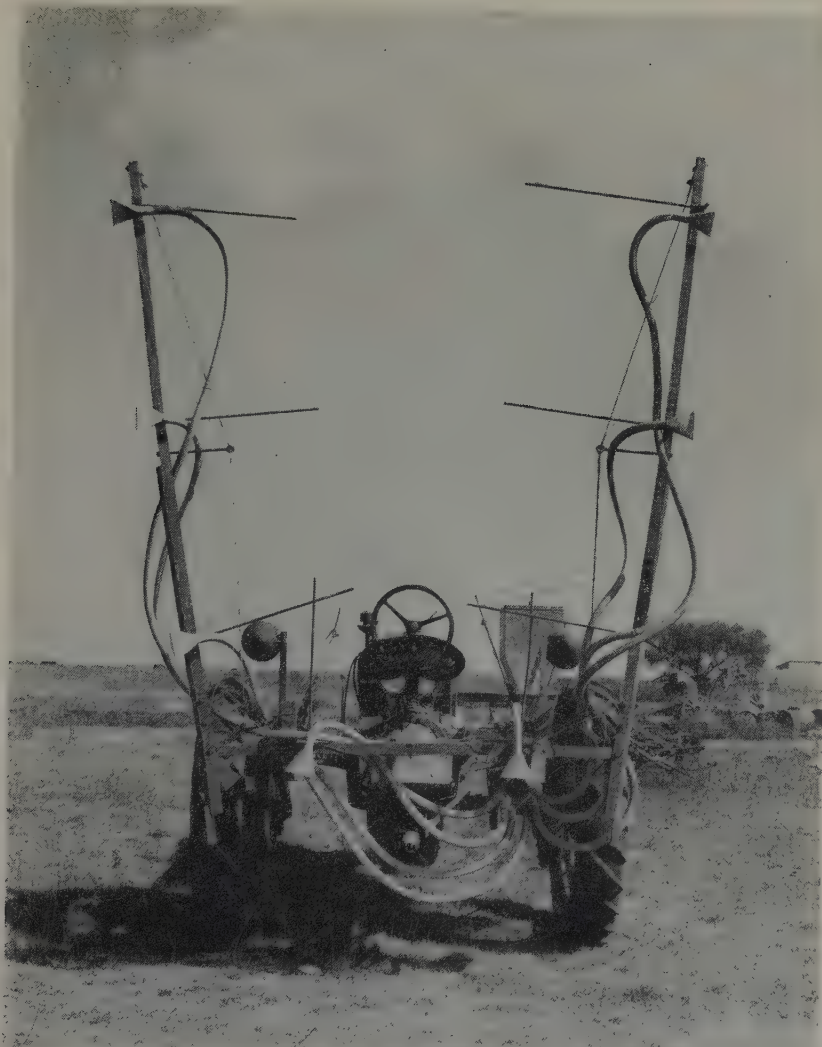
2. TWO-ROW TRACTION DUSTER.



1. AN EARLY-MODEL CART DUSTER DEVELOPED FOR DUSTING COTTON FOR BOLL WEEVIL.



2. A FIVE-NOZZLE POWER-OPERATED CART DUSTER.



TRACTOR DUSTER WITH EIGHT NOZZLES, WITH BOOMS FOLDED FOR PASSING THROUGH GATES.



AIR PHOTOGRAPH OF DIFFERENT TYPES OF DUSTERS IN OPERATION.

Left to right: airplane, tractor duster, cart power duster, traction duster, saddle duster, and rotary hand duster.



1. TYPE OF HIBERNATION CAGES FILLED WITH SPANISH MOSS, CORNSTALKS, OR OTHER SHELTER MATERIAL USED FOR STUDYING WINTER SURVIVAL OF THE BOLL WEEVIL.



2. FIELD SHOWING THE DIFFERENCE IN YIELD OF DUSTED AND UNDUSTED COTTON.

Plot on left was dusted with eight effective applications of calcium arsenate plus 1 percent nicotine-sulfate; plot on right was not dusted. Yield averaged 1,335 pounds of seed cotton per acre in dusted cotton and 392 pounds in the undusted cotton.



1. INDIVIDUAL PLANTS SHOWING INCREASE IN BOLLS FROM BOLL-WEEVIL CONTROL.

Left, dusted plant; right, undusted plant.



2. CHEMICAL DEFOLIATION OF COTTON.

Note absence of squares and small bolls, and mature bolls beginning to open. Photographed September 26, 1944, about 6 weeks before frost.

THE INDISPENSABLE HONEYBEE

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[With 4 plates]

Of all the insects in the world probably no one species is more widely distributed than the honeybee. Its habitat ranges from Alaska to the Tropics. It is found in all intervening places in that great stretch of latitude—in the mountains, in the sultry valleys below sea level, in the deserts, plains, in fact wherever flowering plants occur. Honeybees are not indigenous to all continents of the world, but they have become introduced and established essentially in all parts occupied by man.

If the statement seems too strong that the honeybee is more widely distributed than any other of our common insects, it can be said conservatively that the product of the bee is the most widely produced of man's food. Even such common foods as wheat and milk are not so universally known.

Honeybees were busily engaged in making honey and beeswax before the advent of man. Honey and wax of the bee were waiting in readiness for our earliest ancestors at the beginning of their evolutionary climb. In time they learned of the sweetness of honey and that wax could be employed for many purposes. For centuries honey was the only sweet, and it and beeswax were regarded so highly by the ancients that they wove into their religious ceremonies in one way or another frequent references to honey, wax, and bees. Symbols representing various phases of bee husbandry are found in the earliest recorded histories. Man throughout his existence has been closely associated with the honeybee.

Honey and beeswax were used in the payment of taxes and as indemnity. Conquered tribes and peoples paid off reparations in the form of honey and wax. To the present day beeswax plays an important part in the rites of the church. A beehive forms the central motive of the great seal of the State of Utah.

In spite of this close association, which goes back untold centuries, the honeybee has not acquiesced to man's influence in the same manner as have the domestic animals of our present day. In truthfulness it can be said that there are no domesticated honeybees. The life and the habits of the honeybee are the same today as when man first discovered that the product of these well-armed insects was worth risking life and limb. The social life of the bee with its complex division of labor and its various sexual forms have largely defied all effort to change its nature better to adapt it to man's use. The free nature of the bee and its insistence on mating in the wide open spaces have been the chief stumbling blocks in efforts to improve or to domesticate the honeybee. The sexual development and the mating habits of bees are so different from that of the domestic animals that essentially nothing has been done through selection and breeding to improve the honeybee. As an illustration of this difference the male bees, the drones, are produced parthenogenetically; that is, the drone has no father but he can boast of a grandfather. Queens can give birth to male bees without mating and, even when they are mated, the mating has no effect on the male offspring.

Research workers have delved into the early records of man and written volumes on the antiquity of beekeeping; but, since the intent of this article is to acquaint readers with some facts of man's current dependence on bees and how they are handled, it will be necessary to leave the romantic past in favor of the equally romantic true story of today.

There is more to beekeeping than meets the eye. To the average person it has to do with the production of honey and beeswax. Other than those who have had actual experience in keeping bees, most persons have little conception of how they can be handled and made to work for their owners. There is little mystery about the production of most of our common foods. There is no mystery about the source of milk, butter, and eggs, and the production of fruits and vegetables and their route to the ultimate consumer are matters of everyday knowledge. On the other hand how can bees—wild, undomesticated insects—be directed to produce honey and beeswax? How are these products taken from the bees? Is it necessary to put honey through a manufacturing process before it is ready for consumption?

There was a time when beekeeping was thought of simply in terms of honey produced, but times have changed. Beekeeping now has a much more important part to play. The value of bees as agents of cross-pollination far outweighs the monetary value of the annual output of honey and beeswax.

Why do we hear so much about pollination these days? Is it a new fad or fancy, or is there some basic reason for emphasizing this

subject? In grandfather's day and before his time this subject was seldom mentioned. The land was rich; there was little soil erosion, and for the most part the production of farm crops was satisfactory. As demands for agricultural products increased, farming operations enlarged, and with this came many new problems, one of which was pollination.

Sex plays as important a part in the plant kingdom as it does in the animal kingdom, but in a less obvious manner. Many plants contain both the male and the female elements on the same plant. This is true of all the grasses. Corn, wheat, barley, rye, oats, Kentucky bluegrass, and other grasses all belong to the great grass family. Pollen from the male part of the plant must come in contact with the female element if seed is to result. The corn tassel bears the male element which is the source of millions of tiny pollen grains. The long fine silks which protrude from the ends of an ear of corn are a part of the female element, one silk being attached to each newly formed grain. For this to develop to full size it is essential that a grain of pollen come in contact with the end of each silk. When this happens, the pollen germinates and sends a long tube down throughout the length of the silk through which the male germ migrates and eventually unites with the female cell. Without this union the ear of corn would be abortive and produce only a misshapen naked cob.

Because of the extraordinary number of pollen grains, it has been estimated that an acre of corn will produce in the neighborhood of 300 pounds of pollen. There is more than enough to go around, so that each strand of silk is assured its grain of pollen. Grass pollen is light in weight, easily blown about and carried by wind currents. All grasses are wind pollinated.

Let us look at another kind of plant—one with a more conspicuous flower than is usually found in the grasses—an apple tree for example. Each apple blossom contains both the male and the female element. For an apple to develop, a grain of pollen must fall on the stigma of the flower. The apple, however, like many other flowering plants, will not produce fruit with its own pollen. The blossom of a Jonathan apple must receive pollen from an entirely different variety of apple. This introduces an interesting complication. Apple pollen is heavy and sticky; it cannot be carried by the wind. How then is pollen from one tree brought to another which may be many yards away? There is only one answer—through the medium of insects which live on nectar and pollen.

The mode of reproduction, that is, seed or fruit formation, is slightly different from that of the apple in plants belonging to the cucumber family. Plants such as watermelon, cantaloupe, pumpkin, and cucumber, instead of having both sexual elements in the same blossom,

contain two kinds of blossoms; one is all female and the other is all male. Here again pollen must be carried from the male flower to the female. Since pollen from these plants is also sticky and heavy, the indispensable services of pollinating insects is apparent.

There are still other types of plants in which a single plant produces only male flowers, while another plant of the same species bears only female flowers. The wild persimmon and holly are good illustrations of this type. Since the wind cannot be depended upon to disperse the pollen adequately, insects again come into the picture.

There are approximately 50 cultivated crops grown in the United States that require insect pollination. In addition to those already mentioned, there are many other important plants—for example, alfalfa, sweetclover, red clover, alsike clover, white Dutch clover—which must have each tiny flower visited by an insect in order to produce seed and thus perpetuate themselves. Pollinating insects are either essential or highly desirable in the production of seeds of many vegetables, such as carrot, onion, cabbage, cauliflower, and Brussels sprouts, to name only a few.

Insect pollination is a “must” in our present-day agriculture, but why is it more important today than it was 30 or 40 years ago?

There was a time in the history of agriculture, and not so many years ago either, when it was not uncommon to hull 6 to 10 bushels of red clover or alfalfa seed per acre. It is only rarely that such production is experienced today—in fact, the average yield of both these crops for the United States is slightly under 1 bushel per acre. Yet alfalfa and red clover grow just as well and blossom as profusely as in bygone days. But why has seed production fallen so low? Could inadequate pollination be one of the contributing factors?

There was at one time in this country an adequate population of native insects to take care of all pollination needs. These are insects that maintain themselves and raise their young largely on pollen and nectar. Their whole livelihood depends upon their flower-visiting habits. As farming operations expanded, the nesting sites of many of these insects were destroyed. Where the population of native insects could adequately pollinate a 10-acre field of clover or alfalfa, the same number of insects fell woefully short when the acreage jumped to several hundred acres. Since most plants have blooming periods of short duration, it is only logical that the numbers of pollinating insects be stepped up in proportion to the increase in acreage if seed yields are to be adequate and profitable. We have gone ahead increasing acreages manyfold but have made no effort to provide a proportionate increase in the number of pollinators.

Many factors have contributed to the decline of native pollinating insects. The plowing and clean cultivation of large tracts of land deprive these insects, many of which build their nests in the ground,

of their natural nesting sites. Rail fences which were so difficult to keep clean of vegetation afforded ideal places for these insects to nest. The picturesque rail fences have been replaced largely by well-kept wire fences, thus driving the pollinating insects farther and farther away from the crops which the farmer can grow profitably only when these insects are within flying range of his fields.

Forest and brush fires have further decimated our population of beneficial insects. The tremendous increase in the use of arsenicals is taking a huge toll of native bees, as well as of honeybees, whose essential help we are only now beginning to appreciate.

The honeybee, the most numerous of all pollinating insects, is not native to the United States. It was brought to this country by the early settlers and became known to the Indians as the "white man's fly." It is now thoroughly at home in its new habitat. Swarms that escape from commercial apiaries make their way very nicely in the protection of a hollow tree or in the hollow pillars of our front porches, a place, incidently, where they are not always welcome.

The honeybee, being exclusively a flower-visiting insect, does its share in pollination. It is estimated that honeybees are responsible for over 80 percent of all pollination effected. When swarms of bees escape and go to the woods they are subject to the same hazards as the native bees. Consequently their population in a wild or native state is not building up. This leaves the only stable source of pollinating insects in the hands of beekeepers.

The decline in seed and fruit production is serious in those crops that require insect pollination. Utah at one time was our principal alfalfa-seed-producing State. In its best year, 1925, Utah produced close to 25 million pounds of alfalfa seed. This figure has fallen steadily until the current annual production is less than 4 million pounds. Red clover and other legumes are in the same plight. A good stand of red clover as we see it in almost any locality carries enough blossoms to produce 10 or 11 bushels of seed per acre. The average production for the country is 0.9 of a bushel. Pollination is inadequate to say the least.

Pollinating insects have certain human characteristics. They will not fly farther for food than they have to and always select the richest and best source. Sweetclover is a favorite food plant of honeybees and of most other pollinating insects. It secretes an abundance of rich nectar. The flowers are small and the bees can easily obtain nectar and pollen from them. In contrast, it is more difficult for bees to obtain pollen from the alfalfa blossom, and ordinarily it does not produce so much nectar as does sweetclover. When fields of the two plants are grown in the same locality, the bees will work on the sweetclover in preference to the alfalfa. This preference is so conspicuous that for a given acreage there may be 1,000 bees on the sweetclover

to 1 on the alfalfa. Under such circumstances it is almost impossible to produce a crop of alfalfa seed, since every tiny blossom of alfalfa must be visited by an insect if seed is to result.

Neither farmers nor agricultural experts have paid much attention to how the growing of one crop in proximity to another affects the activities of pollinating insects. Sometimes the natural flora is more attractive to bees than are the cultivated crops. Under such circumstances the farmer is bound to reap a thin harvest.

Is there any remedy for this? More attention can be paid to the sequence in planting crops that compete for the visitation of pollinating insects. Plant breeders could well afford to give consideration to breeding for factors that make plants more attractive to insects. Farmers can also leave protective nesting sites for the wild pollinating insects. They can keep bees of their own or, better still, encourage beekeepers to establish permanent apiaries within flight range of their fields.

Bumblebees are among the most efficient of all pollinating insects. With their long tongues, considerably longer than those of honeybees, they are especially valuable in the pollination of red clover, which has a deep corolla from which honeybees can obtain nectar only with difficulty. Bumblebees are not so plentiful as they used to be. The use of insecticides and other farming practices threatens to extinguish these useful insects. It is still the favorite sport of all farm boys to fight bumblebees and rob their nests of a few thimblefuls of hard-earned honey. Why must the farmer continue to destroy one of his best allies—one who can contribute so significantly to bumper crops of clover seed, fruit, and melons?

By and large the most immediate remedy for inadequate pollination is through the intelligent use of honeybees. This is the only pollinating insect that can be moved from place to place and installed in fields, when and where they are needed. Unfortunately, most farmers do not want hives of bees on their premises. Once in a while a farm animal or hired hand is stung or the owner himself may be the victim, with the consequence that bees are ordered off the place. What a sad state of affairs it is that beekeepers actually have to pay rental to farmers for small out-of-the-way pieces of land upon which to place their beehives. This is one reason why apiaries are not a common sight as one drives through the country. The beekeeper has to place his hives far from the farm buildings and from good roads. In such locations the hives are subject to pilfering, and it is costly for the beekeeper to manage them properly. If farmers understood the part that bees play in more bountiful fruit crops, surely they would welcome beekeepers with open arms. That day must come!

At the moment the important agricultural job of providing pollination, inadequate though it may be, is dependent on the market price of honey. Queer relationship indeed! In volume of business done the production of honey cannot compare in importance with most branches of agriculture. Beekeeping is widely scattered. Almost every county numbers a few beekeepers. Because of the cost of transportation over so wide a territory, it is difficult to concentrate large quantities of honey for commercial distribution. The color, flavor, and consistency of honey vary depending upon where and from what it is produced. Buckwheat honey of our Eastern States has a strong flavor and is almost black; that from fireweed in the Pacific Northwest is water-white and mild in flavor. This great variation imposes a problem to food packers who like to maintain uniform and standard packs of whatever they merchandise. As a consequence, much of the honey is sold by producers directly to local consumers. Not more than 25 or 30 percent of the honey produced in the United States finds its way to large honey-packing plants. Another reason why commercial processors of food may not be so interested in honey is that it requires little or no processing. Honey can be made no better than it is when it comes from the beehive. For these and other reasons, this very delicious food is not advertised nationally. The price of honey is not stabilized or backed by large financial corporations. The vagaries of the market seem always to hound the beekeeper, and on top of it all his product has to compete with highly advertised manufactured foods, such as jams, jellies, and sirups. Whenever the price of honey falls, there is a lag in enthusiasm for beekeeping and the number of colonies is reduced. While this results in less honey per capita, perhaps not too serious a matter, what is more important is that fewer honeybees are available for pollination. Consequently, the production of many crops seemingly far removed from beekeeping is adversely affected.

Growers of orchard fruits have learned that bees are necessary for a full set of fruit, and many of them rent colonies from beekeepers to place in the orchard during blossoming. One would suppose that such an arrangement was as beneficial to the beekeeper as to the fruit grower, but this is not necessarily the case. Apple-blossom honey is almost unheard of. Colonies of honeybees shortly out of winter quarters are not populous enough early in the spring to make honey from apple blossoms. Colonies have to be strong and populous before they can make more honey than the bees require for their immediate needs. Fruit blossom is good for the bees to build up on, but they seldom if ever make honey from it. Also many bees are poisoned through spraying operations and so more and more beekeepers are reluctant to move bees to the orchards even when paid for it.

As yet, growers of such crops as onion, carrot, and legume seed have not realized the necessity of inducing beekeepers to place colonies close to such fields. Beekeepers receive no compensation for the pollinating work which their bees do. The sale of honey, therefore, carries the whole burden of keeping bees available for pollination. The time is probably not far distant when wise men will see the necessity of stabilizing and improving the honey market or else work out an equitable means of compensating the beekeeper for his contribution to crop production.

With the realization that many branches of agriculture cannot survive without the cooperation of a widely scattered and healthy beekeeping industry, more and more persons are becoming interested in trying their hand with bees. A few words of advice may not be amiss.

There is already a big brotherhood of beekeepers. The exact number of persons keeping bees in the United States is not known, but it is estimated to be in excess of 500,000. Of these, probably less than 5,000 depend on beekeeping as a principal means of livelihood. Five hundred colonies are considered to constitute a full-time job, while the largest operators will manage up to 10,000 colonies. The other operators are amateurs, back-lot beekeepers, and many who are in beekeeping as a part-time job, keeping from 50 to several hundred colonies. The production from the 5,466,000 colonies kept in the United States in 1945 was in excess of 225 million pounds of honey.

Almost every State has an active beekeepers' association, and in many places the beekeepers are organized on a county basis. In addition there are numerous bee clubs of one kind or another. A wide-awake group of city beekeepers meets monthly in the heart of New York City. A beginner will find many kindred spirits and persons with whom to compare notes.

To be successful with bees one must like to work with them; capital alone is not sufficient to insure a successful business. Partnerships in which one party furnishes the capital and the other the knowledge are rarely successful in beekeeping. It is mostly a one-man business.

A successful beekeeper is a person to be envied. At all times he is his own boss. During the summer months he works as hard as anybody, but after the harvest he can relax. Even during the height of the active season a good operator can take a few days off to attend a beekeepers' meeting or engage in a fishing expedition. The bees do not require the daily attention that other types of livestock demand.

In a good season a well-managed colony should produce close to 100 pounds of honey. Under expert management and in a good honey-producing locality, several hundred pounds per colony are often harvested. At the same time and place, but poorly managed, a colony may not obtain enough honey to carry it through the winter.

It is essential that the colonies be kept in proximity to an abundant source of nectar. This may be one-quarter mile to 1 mile away from where the colonies are actually situated. Acres of nectar-secreting flora should be within the flight range of the bees.

While there may be literally hundreds of species of flowers upon which the bees work for nectar or pollen or both, in any given locality there are usually not more than two or three plant sources from which the bees can make more honey than they require for their own keep. Thus there are in the United States, perhaps, some three dozen or so species from which 90 percent of the commercial honey is derived. The clovers, including alfalfa, stand high in the list of principal honey plants. Red clover is an exception in that it seldom furnishes the beekeeper with extra honey. Other important sources are orange, tupelo, buckwheat, basswood, cotton, fireweed, star-thistle, sourwood, gallberry, and mesquite. Within limited areas, there may be other plant sources of a local nature that enable the beekeeper to obtain a surplus of honey.

Since beekeeping is so unlike gardening or taking care of livestock of any kind with which most of us at one time or another have had limited experience, a person who contemplates a career as a beekeeper, on either a large or a small scale, should not start with more than two or three colonies. This will keep the investment in bees and equipment low and gives the beginner some concrete foundation for deciding whether or not to go on.

There are some 250 beekeepers scattered through the southern States and California who specialize in furnishing bees to beginners or to established beekeepers who wish to enlarge their operations. Two or three pounds of bees and a queen are shipped by express or mail in wire-screen cages. The cost for a 3-pound package with a laying queen is approximately \$4 to \$4.50 and contains sufficient bees, from 11 to 12 thousand, to constitute a nucleus of a colony. If the new unit is established early, that is during fruit bloom, it may develop into a sufficiently strong colony to produce a worth-while crop of honey the first season. A beginner, however, should feel satisfied if he gets his new pets in good shape to produce a crop the second year.

The hive equipment will run from \$10 to \$15 per colony, depending upon the type of hive and the amount of extra equipment purchased. A study of the catalogs of manufacturers of bee supplies will help in making a proper selection.

A beginner should wear a veil when learning to handle bees. A timid or nervous person would find assurance in a pair of bee gloves. It is seldom that bees sting through clothing and so no special equipment is needed to protect the body. It is advisable to tie string around the trouser legs and a lady might feel greater freedom from fear if she wore slacks.

All beekeepers, no matter how skillful they are in handling bees, receive occasional stings. To the inexperienced, the reaction may at first be rather severe with considerable swelling and itching, but a season's work with bees usually results in the development of some immunity against the venom.

In a short time one should learn to handle bees with confidence and seldom receive a sting. The beginner soon learns that bees are cross and irritable on cold and cloudy days and that it is best to open the hive when the weather is warm and the bees are busily engaged in the fields.

Each colony has its own individuality. One may be quiet and gentle, while its next-door neighbor may be of a hot temperament. The gentlest bees are not always best for honey production, but on the other hand there is little pleasure in working with a colony that is ever ready to sting—no matter how much honey it produces.

It must be kept in mind that bees are undomesticated animals. The average life of a worker bee during the active season of flight is only about 6 weeks, so that little or nothing can be done to train them to do what their owner wishes. By the same token there is no chance for the bees to learn who their master is. An expert beekeeper can go into a strange apiary and handle the bees with as much assurance and confidence, and as good results as can the owner himself. It is essential, therefore, to learn a few of the fundamental principles that affect the reaction of bees. There are books and magazines galore devoted exclusively to the subject of helping the beekeeper master the principal manipulations.

Beekeeping is not all sweetness and honey. Like other types of livestock, bees are subject to several kinds of diseases. Some of these are confined to brood (the young unemerged bees), and there are other diseases that affect only the adult bees. Since some of the diseases are contagious, careful check should always be kept of the colonies to see that they are healthy.

Each colony contains but one queen—the mother of all the bees; her importance to the welfare of the colony cannot be over-emphasized. If the queen should fail because of age—and a queen may live 2 or 3 years—or because of illness, the population of the colony goes down rapidly and may become so weak as to perish. The same persons who furnish bees to beginners also supply extra queens, so that a new queen may be obtained in short order to replace a failing one.

The greatest mistake that beginners make is in not giving the bees sufficient hive space in which to do the work that they can do. Often a beginner, in an effort to keep his investment low, will try to maintain the bees in a single-story hive. A good queen that can lay 1,500 eggs a day and maintain this rate for days at a time requires at least two

hive bodies. These should be considered the sacred property of the bees themselves from which the beekeeper is not to remove any honey. During rainy spells and periods when it is too cold for the bees to fly they must have their daily food. Large reserves of honey should be on hand at all times. Honey that the bees make in addition to that stored in the two hive bodies the beekeeper can claim for himself.

The nectar as brought by the bees into the hive may contain upward of 80 percent water, whereas honey contains only about 18 percent. This excess water has to be removed by the bees. For this purpose, comb space is required, so that the watery nectar may be spread over as large a surface as possible to hasten evaporation; thus more combs are necessary to make the crop than are required to hold the ripened, finished honey.

A colony of bees should never be allowed to fill the hive completely while the honey crop is being made. Shortly before every comb is filled with brood, pollen, or honey, a colony, sensing the end of its job, makes preparation to swarm. In this preparation there is a decided let-down in the storage of honey. Swarming is objectionable from this standpoint.

A colony swarms simply because its living quarters are inadequate—too crowded. The old queen and the majority of bees old enough to fly leave the hive. If the swarm is not captured, the bees light off to the woods, find a hollow tree or a cavity in the wall of a dwelling and build a new home. In the parent hive will be left all the young bees, brood, and a number of queen cells from which one or more new queens will emerge. One of these will eventually head the newly formed colony.

The bees that fly to the fields for nectar and pollen do not deposit the nectar in the cells of the hive. They turn the nectar over to young house bees—bees too young to fly—and it is these house bees that do all the work from that point on in converting the nectar into full mellow-ripe honey. The combination of the young and old bees is essential to produce a crop of honey. When a colony swarms, this very essential teamwork is destroyed. For best honey production every effort should be made to control swarming.

There are other pitfalls in beekeeping beside diseases and swarming. A weakened colony of bees, like a weakened animal, is preyed on by enemies. A colony that is not strong enough to keep its house clean becomes infested with wax moths which, if not tended to, will destroy the combs. A colony too weak effectively to guard its entrance to the hive is subject to attack by bees from stronger colonies. Not only will the robbers carry away the honey, but they will leave in their wake many bees killed in the last defense of their home. Colonies are often weak because they lack sufficient food. Honeybees do

not hibernate as do most other insects. They are in a semiactive state within the hive throughout the long winter, and food in the form of honey must be available to them at all times.

In spite of these drawbacks there is more on the credit side of the ledger. It is not necessary to give bees attention daily. There are periods of weeks or months at a time when they require no looking after. Three or four hours to a colony throughout the year is ample to do all the work necessary. In the spring, and when the honey crop is in the making, a few minutes at the right time does more good than working with the colony for hours at the wrong time. This applies especially to heading off preparations for swarming.

Beekeeping is a challenge to one's ingenuity as well as nerve. Colonies are individualistic, and this has to be taken into consideration in managing them. A person who keeps bees always has an eye to the weather, knowing how sensitive these creatures are to changes in temperature, sunshine, and wind velocity. One's interest in the plant world is immediately stimulated by watching the blossoms upon which bees work.

Taking honey from the hive is not the least joy of working with the the bees. No honey tastes so good as that produced by one's own effort. There is also the satisfaction in knowing that through your efforts and patience the fruit trees of your neighbors bear more bountifully and that as the busy bees wing their way to surrounding pastures, gardens, fields, and orchards they are enriching the entire countryside. They provide a function for which there is no substitute and give their keeper a food which man with all his skill has not been able to duplicate.



WORKER BEE, QUEEN, AND DRONE.

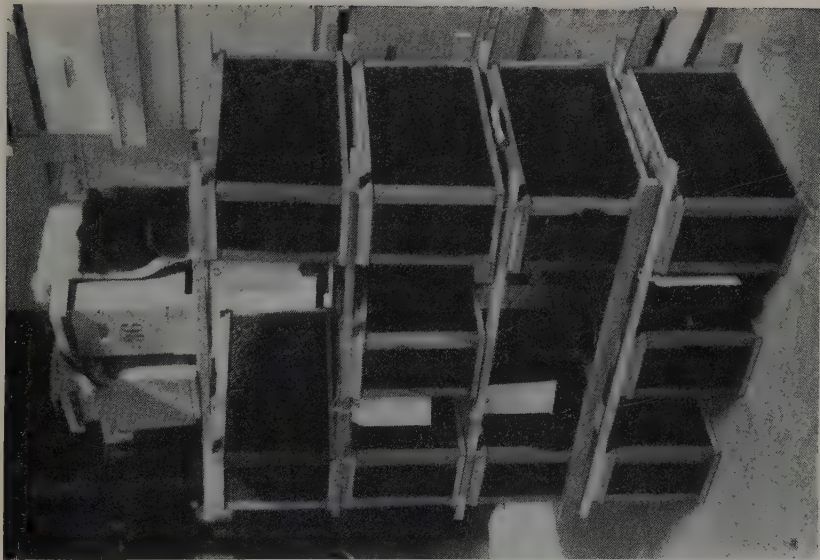
The queen is mother to all the other bees. The worker bees make up the bulk of a colony and in a populous hive may number 60,000 individuals. The drone is the male bee of which there may be several hundred in the hive during the active season. In the fall the drones are driven from the hive to perish.



1. THIS WELL-KEPT BACK-YARD APIARY IS A PAYING SIDELINE. IT IS BOTH ATTRACTIVE AND PROFITABLE.



2. A BACK-YARD APIARY COMFORTABLY TUCKED AWAY FOR THE WINTER.



1. PACKAGES OF BEES WAITING FOR THE EXPRESS-MAN TO TRANSPORT THEM TO THEIR NEW OWNERS.

Each package consists of one queen and 3 pounds of bees. Most package bees come from the southern States and California.



2. A MEMBER OF THE YOUNGER GENERATION RECEIVES A LESSON IN CAPTURING A SWARM.



1. A SWARM THAT HAS BEEN CUT FROM THE LIMB OF A TREE.

Placed at the entrance to the hive, the bees enter of their own accord. 'As soon as all bees have entered, the hive may be moved to a permanent location.



2. WORKING WITH BEES IS PLEASANT, CLEAN, AND ALWAYS OUT OF DOORS.

THE IMPORTANCE OF PLANTS¹

By WILLIAM J. ROBBINS

Professor of Botany, Columbia University, and Director of the New York Botanical Garden

Nothing I have to say here is new; all of it has been known for many years, some of it for a century or more. Yet I believe that the repetition from time to time of facts of fundamental import has its place. Even scientists can on occasion review with profit the broad significance of the material on which they spend their lives. One group of facts of the character I mention concerns the place occupied by plants in the life of man and the economy of nature.

PLANTS THE BASIS OF LIFE

Plants are the basis upon which all other life depends. In the last analysis they supply us with all the food we eat, they maintain the oxygen content of the air and they are the primary source of those important accessory foods, the vitamins. Without plants we would starve to death, die of suffocation, and expire from a combination of deficiency diseases. In addition, plants are the chief means by which the energy of the sun is and has been in ages past caught and stored for us in usable form. Without plants fire would be unknown because there would be no wood or coal or petroleum to burn, and electricity—except as a natural phenomenon—would be at most limited to areas freely supplied with water power.

The essential relation of plants to the food we eat, the air we breathe, and the energy we dissipate with such reckless abandon is based on two of their characteristics. These are their ability to store the energy of the sun's rays in sugar, starch, cellulose, oils, fats, and other constituents of the plant body, and their ability to construct from simple and elementary substances types of chemical compounds necessary for the existence of animals, including ourselves.

¹ Address of the vice president and chairman for 1943 of the Section on the Botanical Sciences, American Association for the Advancement of Science, Cleveland, September 1944. Reprinted by permission from Science, vol. 100, No. 2603, Nov. 17, 1944.

The first of these powers, limited from a practical standpoint to plants which possess the green pigment chlorophyll, is the familiar process of photosynthesis in which the plant transforms water obtained from the soil and gaseous carbon dioxide from the air into sugar and oxygen. In the course of photosynthesis, which occurs only in the light, energy from the sun is stored in the product sugar and in the starch, wood, oils, and fats, or other organic substances constructed by living things from this sugar. The energy we obtain by burning coal, lignite, peat, and petroleum was stored by the activity of plants in the dim past. It represents our capital stock of usable energy and once dissipated cannot be recovered. The energy in wood, sugar, plant and animal oils and fats released by burning or by the metabolism of living things is that part of the sun's energy stored in our time. This can be regenerated within a reasonable period by the activity of plants now growing. Other sources of power, water power, wind power, power from the tides, are minor in comparison with the energy which has been and is being stored by the photosynthesis of plants.

The major features of this essential process were discovered and elaborated by Joseph Priestley, Ingenhousz, Boussingault, and others over a period of about 100 years beginning in 1771 and are taught in every course in botany and biology. The details of how chlorophyll works are, however, still unknown, and the basic and essential character of the process is not yet a part of our national thinking. If it were, the small group of men who are attempting to discover how photosynthesis occurs—that is, how plants store the sun's rays—would receive more encouragement and assistance than they do, and in the discussions of the future of synthetic rubber made from petroleum we would see some consideration given to the wisdom, from the long view, of using petroleum in quantity to make something which can be produced from the air and water by the activity of plants.

Perhaps the significance of photosynthesis for our mechanical age could be more clearly grasped if it were possible to prepare a balance sheet on the world's store of available energy and the rate at which it is being dissipated. This cannot be done. We can say that the coal and petroleum burned annually represents a net loss of potential energy, and we can also say that in time, though not in what time, we will have to depend upon the energy fixed annually by plants unless some other source at present not at our command, for example, atomic energy, is discovered and methods for its utilization devised.

How much energy is fixed annually by plants? Abbot has estimated that the energy given off by the sun amounts to the equivalent of 4×10^{23} tons of coal annually, of which the earth intercepts a small fraction, the equivalent of 2×10^{14} tons of coal. According to Berl, plants fix each year 2.7×10^{11} metric tons of carbon, which is the

equivalent of somewhere near 3×10^{11} tons of coal. If these figures are approximately correct, then about 0.15 percent of that part of the sun's energy which falls on the earth is caught annually and stored by plants.

Riley has estimated the photosynthetic efficiency of the world as a whole to be 0.18 percent and that of the land areas 0.09 percent.

Another set of data leads to somewhat the same conclusion. Transeau calculated that 1.6 percent of the sun's energy was utilized by a field of corn in Illinois during the 100 days of its growing season. Since for much of the rest of the year a cornfield lacks vegetation it would appear that something less than 1 percent of the sun's energy annually reaching corn land in Illinois is fixed. In some parts of the Tropics and other sections of the world where vegetation is active the year round this proportion would be larger; on the other hand, in the Arctic and in deserts it would be much less. We may be justified, therefore, in assuming that the annual energy fixation of plants approximates the equivalent of 3×10^{11} tons of coal.

This astronomical figure is at first sight quite comforting, particularly when we learn that in energy value it is over 200 times the coal and oil burned in 1938. The difficulty is that most of this annual income is not used. Wood, alcohol produced in fermentation, and plant waste play but a minor part in furnishing heat or mechanical energy because of their inconvenience, expense, or lack of adaptability to modern machinery. We depend at present upon coal and petroleum, the world's capital stock of available energy, to supply the amount required for this mechanical age.

Berl has reported a method by which motor fuel equal in many respects to petroleum can be produced from cellulose, starch, sugar, and other carbohydrates, thus offering the possibility of replacing our stock of usable stored energy by utilizing part of the current day-to-day income. Carbohydrates only can be used by Berl's method; lignin, protein, oils, and fats are unsuitable as crude materials. However, if all the carbohydrates in all the plants were used as Berl suggests, and this is obviously impracticable, we would have but 6 times the present annual consumption of petroleum and less than 2 times the equivalent of the annual world consumption of petroleum and coal. If all the world used coal and petroleum as we did in this country in 1942, the total energy fixed by plants would be but 25 times that dissipated and all the carbohydrates made each year would yield about one-third the amount the world would need. We can only guess what these figures would be if we knew the energy consumption for the war years of 1944 and 1945.

Two years ago the National Science Fund asked a representative group of outstanding scientists to list the problems with which scien-

tific research should be concerned in the postwar era and on which special emphasis should be placed. Future sources of energy stood third on the list. Its importance was surpassed, in the judgment of these men, only by the analysis and study of human behavior and the general field of medical problems.

I shall not linger long on the second characteristic of plants so necessary for the existence of other life on this planet; that is, their ability to construct from simple and elementary substances types of chemical compounds essential for animals. Their capacity for making sugar from carbon dioxide and water, constructing amino acids from inorganic nitrogen and organic-carbon compounds, and for synthesizing vitamins enables us to live. Plants are able chemists and there is no substitute for them.

PLANTS AND RESEARCH IN SCIENCE

It would seem perhaps appropriate to terminate a discussion of the importance of the plant kingdom after having pointed out the essential relation of plants to our sources of energy and the dependence of all life on their existence. However, plants do more than fill our stomachs, warm our bodies, and help us to go quickly from here to there. For example, plants are useful for the investigation of problems in science. For this purpose they have certain advantages. They can be grown in large numbers, and we have no compunction in destroying them in quantity if it is desirable for the purposes of the research. Their firm, well-delineated cell walls, general structure, and methods of reproduction make them well adapted to the investigation of certain kinds of problems, and their infinite variety in morphology and physiology offers opportunity to select an organism best fitted to serve as experimental material for attack on a particular question.

The study of plants played a major part in the development of our knowledge of cells and the formulation of the cell theory. Cells were first described by Robert Hooke in 1665 from charcoal, cork, and other plant tissues. The discovery of the nucleus is generally ascribed to Robert Brown, botanist, who made his announcement in 1831. The first careful description of cell division we owe to the botanist Hugo von Mohl, who introduced the term "protoplasm" in its present sense. Chromosomes were figured by the botanist Anton Schneider in 1873 and first adequately described by Strassburger in 1875.

In many other directions we find that research with plants has led to fundamental discoveries. The investigations of Payen and Persoz in 1833 on the diastatic activity of germinated barley opened the door to the field of enzymes. Mendel's laws, the foundation of

our understanding of heredity and genetics, were discovered by experimenting with peas. The idea of hormones was first presented by the botanist Sachs in 1880. The essential nature of the so-called minor essential mineral elements, for example, manganese, copper, and zinc, was demonstrated by Bertrand and his coworkers for the black mold *Aspergillus niger* considerably before their importance in animal nutrition was recognized. The discovery of the nature of virus diseases to which belong the agents responsible for smallpox, yellow fever, influenza, poliomyelitis, virus pneumonia, foot and mouth disease, hog cholera, rabies and many other afflictions of man, animals, and plants began with experiments by Iwanowski in 1892 on the mosaic disease of tobacco and was completed by Stanley in 1935 by the isolation from tobacco afflicted with mosaic of the active agent as a nucleoprotein of high molecular weight. The influence of day length on reproduction was demonstrated for plants by Garner and Allard some years before the correlation of reproductive activity in animals and day length was investigated.

Perhaps nowhere is the importance of work with plants for scientific objectives of general application demonstrated better than that which has been carried on with yeast. Pasteur's investigations on fermentation contributed in a major way to the germ theory of disease and to his later discoveries in the field of medicine. Investigations on the chemical changes induced in carbohydrates by yeast have had an immense influence on our knowledge of respiration and the intermediary metabolism of carbohydrates in animals, including man. At least two vitamins, pantothenic acid and biotin, were discovered from a study of yeast.

Many other examples could be cited illustrating the importance of research on plant material. What I have said, however, will suffice to show that the study of plants has given us in the past, as it will in the future, concepts of general significance in biology, a knowledge of principles applicable to other living things, including ourselves.

RECREATIONAL VALUE OF PLANTS

I scarcely need call your attention to the recreational value of plants. The opportunity to enjoy flowers, shrubs, and trees acts as an antidote for the artificiality and tension of city life, relieves the drabness and monotony so frequently associated with existence in a small town or in the country, and satisfies a deep-seated desire in all of us. It cannot be expressed in units of value, though it has been recognized in art, poetry, architecture, and design since the beginnings of recorded history. I see it evidenced by the thousands of films exposed by a part of the million or more people who visit the New York Botanical Garden

annually; by the letters which come to my desk from those who feel impelled to tell me "the great pleasure it is to wander through flower gardens and conservatories and to spend quiet, peaceful, restful hours in the grounds," to quote from one of them; by the nearly 150,000 people who in 1938 attended the International Flower Show in the Grand Central Palace in New York City between Monday noon and the succeeding Saturday night with an admission charge of \$1.10; by the universal interest in gardening and the numerous organizations associated with it, garden clubs, Rock Garden Society, Iris Society, Dahlia Society, Herb Society, Rose Society, Begonia Society, Succulent Society, and so on; by the elaborate gardens maintained by the wealthy and the plants raised on window sills in country kitchen and city apartment.

Someone has said that gardening and a love of gardens are essential components of a full, sane, and rounded life, and traffic with the soil and the green things that grow from it is one of the noblest and most healthful associations man may adopt. To own a bit of ground, dig it with a spade, plant seeds and watch them grow is a most satisfying thing, and fondness for such activity often comes back to a man after he runs the round of pleasure and business. As Henry Ward Beecher once wrote, every book which interprets the secret lore of fields and gardens, every essay that brings us nearer to an understanding of trees and shrubs and even weeds is a contribution to the wealth and happiness of man.

A garden gives the possessor fruit, vegetables, and flowers; it also teaches patience and philosophy, pacifies and heals the body and the mind. This is recognized in the employment of gardening in occupational therapy by hospitals and prisons, a practice which has been used successfully and is increasing. This was not always so. Oscar Wilde, writing of his own experience in an English jail, said:

But neither milk-white rose nor red
May bloom in prison air
The shard, the pebble and the flint
Are what they give us there
For flowers have been known to heal
A common man's despair.

At the New York Botanical Garden some years ago we received an anonymous gift of money from an individual who stated that it was sent because the opportunity of enjoying the plantings in the Garden had prevented self-destruction. If one person was impelled to express his appreciation in this fashion there must have been many others less articulate or with smaller need who have felt the influence of plants in times of stress. I believe that in the brave postwar world many are now planning, gardening will be recognized and given an important place because of its occupational and spiritual values.

May I add a word of caution. We need nothing but our senses to enjoy the beauty of flowers, but the deeper satisfaction of knowing them and growing them requires a breadth of knowledge and experience surprising to the uninitiated. So long as any man out of employment is considered to be a capable gardener, and seed catalogs are looked upon as adequate texts, gardening is likely to be a series of disappointments which only the persistent will survive. Gardening as a profession requires training, practice, and a body of special information, as other professions do, and the amateur, whether individual or corporate does well to look to the professional for guidance and for help. The Royal Botanic Gardens at Kew and at Edinburgh as well as similar institutions on the continent have long recognized gardening as a profession and have conducted courses of instruction in theory and practice. In this country few institutions have as yet concerned themselves with this aspect of education, though in the postwar period there is going to be a considerable need for it.

ECONOMIC IMPORTANCE OF PLANTS

Everyone recognizes the economic importance of the common field crops, wheat, oats, and corn, of the vegetables and fruits, and of lumber. These are items in our everyday living. Not everyone realizes, however, how many other products are obtained from plants. They are the source of linseed oil, corn, and coconut oil, turpentine, lacquer, varnish, and resin, coffee, tea, and other beverages, perfumes, flavorings, and spices, drugs and insecticides, paper, cordage, and clothing, cellulose for artificial silk, and a hundred other useful products. The plant-extractives industry alone, including drugs and flavorings, probably amounts in the United States to between 100 and 160 million dollars annually. It took a war, a war which cut us off from normal supplies, to make us appreciate how much our economy and our comfort and convenience depend upon many of these plant products from distant places. Rubber and quinine are two of the most generally known, but there are many others, for example, the sponge of the luffa gourd, the insecticide pyrethrum, chicle for chewing gum, the drug ergot, agar agar, and cork. And yet in spite of the varied materials we now obtain from plants the potentialities of the plant world are but partially explored. What might be called economic botany is largely an inheritance from our untutored ancestors who obtained their information over the centuries by trial and error. Very little systematic effort has been made to explore the plant kingdom with the idea of exploiting products as yet unknown or unused. The wide contacts brought through this war to hundreds of thousands of our young men, many of them already trained in science, may result in new and important uses for plants. The opportunity exists because not only

are familiar plants incompletely investigated, but there are considerable areas of the earth botanically unexplored and thousands of species of plants still unknown to science. Any one of them might become as important to us as *Penicillium notatum*.

I cannot close this discussion of the economic aspects of plants without referring to their importance in disease and decay. It is not my intention, however, to discuss bacteria, yeasts, and molds as causes of disease in other plants and in animals and man, nor to elaborate on their relation to decay except to call attention to the importance of the fungi in rotting wood and cloth, molding food, short-circuiting electrical instruments, and deteriorating optical equipment in the Tropics. Although those of us who live in the Temperate Zone are acquainted with the fungus rots of telephone poles, railroad ties, and house timbers and the minor losses from mildewed curtains or moldy food, we have little conception of the destructiveness of molds in the moist Tropics. Their control is a matter of major concern.

Another way in which plants contribute to our economic system is through the association of micro-organisms in the formation of various products, for example, cheese which depends upon the activity of the lactic acid and other bacteria and various molds; beer, wine, and other fermented liquids produced by yeast; sauerkraut, vinegar, soy sauce, and many others less well known or desirable. Bacteria, yeasts, and molds as we learn to know them better are increasingly used for producing specific chemical compounds which are beyond the skill of the laboratory worker or which can be made more cheaply by the micro-organism. Alcohol, acetic acid, acetone, glycerine, citric acid, gluconic acid, and riboflavin are some of these compounds. The most recent and illustrious addition to this list is, of course, penicillin.

"Botany," said Thomas Jefferson, "I rank with the most valuable sciences whether we consider its subjects as furnishing the principal substances of life to man and beast, delicious varieties for our tables, refreshments from our orchards, the adornment of our flower-borders, shade and perfume of our groves, materials for our buildings or medicaments for our bodies."

Jefferson wrote these words in 1814. Priestley had but recently demonstrated that plants produce oxygen; the uniqueness and importance of photosynthesis was still to be recognized; coal and petroleum were still to be developed; vitamins and amino acids, the relation of plants to them and their importance in animal nutrition were unknown; rubber was a plaything; the relation of bacteria and molds to disease and decay was still to be discovered and penicillin was a long way in the future. Thomas Jefferson estimated the importance of plants on the basis of the knowledge about them available in 1814. What would he have said today?

FUNGI AND MODERN AFFAIRS¹

By J. RAMSBOTTOM, O. B. E.

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It is a little surprising that fungi should have received so little consideration from academic botanists, for they are more numerous in species and in individuals than is the rest of the plant kingdom. They are classed in the vegetable kingdom, for with the old divisions, plants, animals, and minerals, there is nowhere else for them. But they are not plants in the ordinary sense of the word as they have no chlorophyll and there is no evidence that they were derived from organisms so provided. A great amount of research has been carried out during the last half-century to ascertain the precise methods by which green plants build up carbohydrates; but comparatively little attention has been paid to the manifold and diverse physiological processes by which fungi obtain their nutriment. In their search for food, fungi play many parts in the drama of Nature and in modern affairs.

To many the word fungus conveys the idea of something mysterious or foreboding: to others mushrooms and toadstools. J. Bauhin appeared to combine the two ideas when he derived the word from *funus* (funeral) and *ago* (to put in motion), a derivation which John Ray considered appropriate even if possibly not correct.

What is a mushroom? The term is often loosely applied to those larger fungi which are edible, it being assumed that only the field mushroom and possibly one or more of its near allies are safe to eat; the rest, assumed to be poisonous, are grouped together as toadstools. But the assumption puts the facts the wrong way round, for there are less than a dozen species which are in any way poisonous; the vast majority are harmless. It would be illogical to speak of even the 300 or more edible species as mushrooms and the others as toadstools; it seems preferable to call all agarics "toadstools," restricting "mushroom" for the species of the genus *Psalliota*: in this way, moreover, some of our insular and peculiar prejudice against them might be toned down.

¹ Substance of three lectures delivered at the Royal Institution on February 15, 22, and 29, 1944. Reprinted by permission, with additions by the author (enclosed in brackets), from *Nature*, vol. 153, May 27, 1944.

Toadstools have been eaten from the earliest times. There is no reference to them in the Bible, but classical writers leave us in no doubt that fungi were well known as peculiar organisms of strange growth, so well known indeed that they were the subject of puns. Accidents sometimes occurred and, as these seem to be specially noted, it has been assumed by some that the use of fungi as food was regarded as too dangerous to be indulged in. What is more probable was that fungi were a common food, but accidents were especially noted because of the difficulty of distinguishing between wholesome and poisonous species. It was comparatively simple to get a knowledge of what plants and fruits are safe to eat for they are easy to recognize again, they are lasting, and, even if annual, they are constant in their time and place. Consequently they all had names. Fungi, on the other hand, are difficult to describe, and the fleshy ones are of irregular occurrence and of short duration. For this reason we find rules for distinguishing between edible and poisonous species rather than names and descriptions. Many of these rules are still current—"peeling," and the nonblackening of a silver spoon being the most widely believed, and this throughout Europe, possibly owing to their being repeated in the old herbals. All are utterly worthless, even dangerous. There is only one real test. Many have tried it, and as there are numerous records of experiments which ended in disaster, we have a mass of evidence which relieves us of the necessity of personal trial.

It is only in Great Britain that toadstools are rejected as food. Eighty years ago, five or six species were on sale in Covent Garden Market; but later only the mushroom, wild or cultivated, was displayed. It is hard to account for the British prejudice against them. It has been suggested that it is because of our high standard of living, or alternatively because of the absence of well-wooded country: but these do not explain the fear most people have of them.

In Continental countries with hard and long winters, fungi are dried and pickled and form a staple food while the frosts last; they also serve in place of meat during religious fasts. In all Continental countries fungi are sold in the markets, and many towns have special fungus markets. Usually there is some sort of control, and the number of species allowed to be sold varies from half a dozen to more than 300.

Though in Great Britain the chief use of toadstools is as appetizing additions to other dishes, they have a certain food value. There is need of more precise information on this, for many of the old analyses led to extravagant claims. Darwin recorded that the Terra del Fuegians eat no vegetable food except *Cyttaria* and a few berries, whereas Lettow-Vorbeck recounts that when, during the East African campaign of the War of 1914-18 the difficulties with food had reached a most embarrassing stage, the German troops were able to carry on

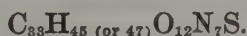
owing to finding enormous quantities of edible fungi which were to them as manna was to the children of Israel.

There are a number of species which have always had a good reputation as edible, which moreover are easy to identify and which cannot readily be confused with any poisonous forms. For those not making a special study of the subject, it is advisable to learn to recognize some of these, rather than to experiment with others about which all that is known is that they are not among those regarded as poisonous.

The most deadly poisonous species is *Amanita phalloides* (including the two white varieties or closely allied species *A. verna* and *A. virosa*). It is responsible for practically all the recorded deaths from fungus poisoning and the death rate is more than 50 percent—indeed, it has been put as high as 90 percent. There is a characteristic period of quiescence after the fungus is eaten, on an average 12 hours, though it may be as long as 40. Death may occur on the first day, but is usually on the third or fourth day. There are apparently four poisons contained in this species: *Amanita* haemolysin (phallin), a glucoside readily destroyed by heat and digestive juices; *Amanita* toxin with a complicated and indefinite chemical structure; and, according to the work of F. Lynen and U. Wieland (1937), phalloidin, which is quickly acting though destroyed by heat, and an additional slower-acting toxin. Death through eating the cooked fungus is apparently due to the heat-resistant *Amanita* toxin. [H. Wieland and B. Witkop in 1940 showed that phalloidin is a hexapeptide with the probable formula



and in 1941 Wieland and R. Hallermayer stated that *Amanita* toxin which they called *Amanitin* has the character of a weak acid and contains peptide-like groupings; the formula is



There are only three poisons present, the report of a fourth being due to impure preparation confusing the findings.] Cures have been reported by the use of a "sérum antiphalloïdien" prepared at the Pasteur Institute; by intravenous injection with 20 percent glucose solution; by intravenous injection with 10 percent sodium chloride solution; by administering the finely chopped-up stomachs of three rabbits and the brains of seven.

Amanita mappa, formerly considered as very poisonous, is edible but not worth eating. *Amanita muscaria*, which contains muscarine, mycetoatropine, and choline, does not cause death in healthy people. The symptoms of poisoning usually simulate alcoholic intoxication, though there are occasionally gastro-intestinal disturbances. *Amanita pantherina* produces similar symptoms.

The remaining species which are in any way dangerous, raw or cooked, are *Lepiota helveola*, *Entoloma lividum*, *Inocybe patouillardii*, *Boletus satanas* and *Gyromitra esculenta*, though some other species are very indigestible and consequently may cause disturbance.

Claviceps purpurea (ergot) is a poisonous fungus of another group. The two different types of ergotism, the convulsive and the gangrenous, are now well known. Five alkaloids have been isolated from ergot: ergotinine, ergotoxine, ergotamine, ergotaminine, and ergometrine. As its name suggests, ergosterol was first extracted from ergot;² histamine also. The use of ergot in childbirth is mentioned by Lonicer in 1582 in the first record of the fungus. At present ergot is the only fungus which figures in the British Pharmacopoeia.

Fungi, being without chlorophyll, have a physiology which in many ways is more animal-like than plant-like. Obviously there are two main sources of food, living organisms and dead organic material. Fungi make use of both—they parasitize all kinds of living organisms, and there is no sort of organic matter not liable to attack. But though they are responsible for the greater part of plant diseases and they cause destruction to stored products of every kind, the changes they bring about are not all to our detriment as living organisms. They act as scavengers reducing dead material into substances available for plant life, and moreover prevent the cluttering up of the earth's surface. The action of soil fungi on plant material was overlooked when untreated jute sandbags were filled with sand and even ordinary earth at the outbreak of the present War. The modern compost heap is a contrivance to bring about the breaking down of similar cellulose substances.

Forest trees are subject to attack by larger fungi as well as by microscopic forms. Timber from such trees is unsuitable for most purposes and, moreover, if not properly seasoned, may continue to rot. Fallen logs and stumps have a characteristic flora, and several of the species occur on wooden fences, gateposts and similar structures; *Lentinus lepideus*, for example, attacks wood pavement blocks, telegraph poles, and railway sleepers.

If wood is to be preserved, it must be kept dry or treated with some fungicide. The chief agent of destruction of structural timber is *Merulius lacrymans*, the dry-rot fungus: there are other fungi causing dry rot, but the damage they produce is trivial. If timber is properly seasoned and then kept dry by ventilation so that it never contains as much as 20 percent moisture, the fungus will not attack it; otherwise damage is almost certain. At the present time, the amount of dry rot in London calls for serious attention. It is easy to understand how

² Ergotoxine has been shown to contain three different alkaloids with their isomers. In addition, ergobasine and its isomer ergobasine have been isolated, together with an isomer of ergometrine.

houses which have been severely bombed are liable to have their timber affected, but blasts have cracked water pipes with a consequent seepage of water through the walls; leaves and other rubbish have caused overflows which run down the walls; shelters have been constructed so that ventilation and even watercourses have been interfered with; ventilation bricks have been stopped up to prevent entrance of gas; or sandbags which became rain-sodden propped up against walls, often over air bricks; houses left unattended, with no heat and leaky roofs; water tanks and pipes bursting, water taps left running in requisitioned buildings—all have played their part in bringing about a good deal of unnecessary waste. Furthermore, there is need for some scientific control over new housing plans or we shall have a repetition of the troubles which affected whole building estates after the War of 1914-18.

In addition to causing diseases of trees, microscopic fungi cause disease not only of crops but also of wild plants. The most striking point about the flora of bombed sites is the rapid appearance of special fungus parasites, as for example *Bremia lactucae* on groundsel. The idea that disease is a result of civilization is very attractive to some minds—but is entirely false.

Fungi are the main causal agents of disease in plants. The losses in different crops vary normally from 2 to 50 percent; figures for the United States for wheat, oats, and barley in 1935 due to rust alone were estimated at 277, 185, and 53 million bushels respectively. There are many ways of combating fungus attacks, the most obvious being the use of fungicides. Much depends upon having a thorough knowledge of the life history of the parasite as well as that of the host plant, for then the fungus can be tackled at its most vulnerable stage.

Some varieties or races of plants are immune to the strain of fungus parasite common in the neighborhood, and much work has been done in the attempt to breed immune races. But it is frequently overlooked that there is often as much variation in the parasite as in the host. Thus the problem of producing a wheat immune to black stem rust theoretically necessitates the building up of a resistance to 177 physiological races, though, practically, only the local strains present in any one area need be considered.

Less than a century ago, when the parasitic nature of many diseases was beginning to be suspected, fungi were thought to be responsible for many human affections. This was a consequence of Schoenlein's discovery in 1839 of the fungus causing favus, which was immediately followed by Lagenbeck's describing the fungus of thrush, and soon afterward by Gruby's description of ringworm. With the gradual recognition of the predominance of bacterial diseases and the abundant problems they presented, mycology, except for the obvious dermatophytosis and actinomycosis, has not received the attention due to it,

especially in Great Britain. Many of the ringworm group are able to live parasitically on domestic animals; some are known to live saprophytically on organic debris, and others have been reported as capable of infecting living plants. Athletes' toe (*Trichophyton* spp., *Epidermophyton*) has become increasingly common in Great Britain during the past few years and is prevalent in certain sections of the fighting services. But there are many less obvious diseases which have been studied principally in France and America. That they exist elsewhere is shown by the recent recognition of histoplasmosis (*Histoplasma capsulatum*) in Great Britain. The symptoms of this disease are protean; they may simulate kala azar or pulmonary tuberculosis—and the prognosis is bad. A recent discovery by C. W. Emmons that small desert rodents constitute an important natural reservoir of *Coccidioides immitis*, the cause of coccidioidal granuloma, is of importance. This disease has been known for about half a century in North and South America and was thought to be soil-borne. The Medical Research Council has recently appointed a committee to report on the situation of medical mycology in Great Britain.

Animals other than those domesticated are also liable to fungal disease. Insects particularly are affected, whole groups of fungi being entomogenous; as, for example, the Laboulbeniales with about 120 genera and 1,500 species, so well monographed by Thaxter. Moreover, it has been shown recently by C. Dreschler that there are a number of species, Entomophthoraceæ and Hyphomycetes, which parasitize nematodes, amœbæ and other small soil inhabitants.

The extent of the damage by fungi to stored products of all kinds is only gradually being realized. The losses in textiles have received most attention and the investigations of the conditions in which cotton and wool become mildewed are influencing the practices of manufacture. The methods of preserving foodstuffs—sterilization, canning, pickling, and so on—are chiefly to prevent mold attack, though they also protect them from bacterial contamination.

The outward and visible sign of specific differences in fungi is morphological as in green plants and animals, but this should not mask the fact that a given species growing under definite conditions always acts in the same way and brings about the same results. Can we so harness any species that it will produce results useful to us? What has Nature herself done in this direction?

Armillaria mellea is a common toadstool which causes a good deal of disease in trees but is also able to live saprophytically. It spreads by means of rhizomorphs, strands of compacted mycelium which look somewhat like flattened, branched, and anastomosing black leather bootlaces. If these encounter potato tubers, they reduce them to mush in 2 or 3 days. On the other hand, if the rhizomorphs meet the tubers of the Japanese saprophytic orchid *Gastrodia elata*, they pene-

trate for only a certain distance and are then held in check. An uninfected tuber sends out a dropper and the process is repeated each year until a tuber is formed which is too small to grow. An infected tuber, however, sends out a dropper which produces an inflorescence the following year. It is obvious that the orchid obtains nutriment from the rhizomorphs, which presumably act as conducting strands. It may be that in some such reversal of parasitism we have a clue to the origin of the more typical mycorrhiza or fungus-root. Orchids are the classical example of obligate symbiosis, the seeds not normally germinating unless infected by the fungus present in certain cells of the roots. In modern methods of commercial orchid growing, either the seeds are infected artificially with the appropriate fungus, or its action is replaced by sowing sterilized seeds on a medium containing sugar.

Forest trees have a layer of fungal hyphæ surrounding many of the absorbing rootlets, the fungi concerned being mainly of the toadstool type. Many perennial plants also have mycorrhizas, but it is not yet certain which fungi are concerned: the usual appearance is suggestive of *Phycomycetes*. Similar associations with fungi occur throughout the plant kingdom.

The association of fungus and alga has resulted in the large homogeneous class Lichens.

Many insects have internal yeasts: indeed, these are supposed to have played a definite part in the evolution of some insect groups. A more obvious harnessing is that of the leaf-cutting ants of South America which, as first described by Bates and amply confirmed since, cultivate fungi of the toadstool type in their fungus gardens. An association in which the fungus seems to be less in subjection is that of bacteria and yeast which are active in various fermented drinks—Mexican tibi, koumiss, kephir, leban, tea cider, ginger-beer plant—some fermenting sugary liquids, others milk.

In addition to these combined masses, which are usually in the form of grains, man in his early history noted that fruit juices or other sugary fluids underwent a change if left for some time: honeycomb washings became mead, grape juice became wine. These much-appreciated changes, the work of yeasts, were not to be left to blind chance, and in the course of centuries the conditions controlling the changes and finally the reason for them became known. Nowadays distillers, brewers, many wine growers and cider manufacturers no longer rely on some general supply or on casual wild yeasts, but maintain pure cultures of special strains of the appropriate species which have proved to give the best results in the conditions of production. Here we have the breaking down of organic matter by fungi to give a desired result. It must be stressed, however, that a fungus acts only in a certain way in definite circumstances.

Pasteur's classical researches on fermentation were a direct outcome of the misfortunes that befell France after the war of 1870. It is surprising how often an odd fact he mentioned more or less incidentally has been followed up by later investigations. Thus during the War of 1914-18, German scientific men turned their attention to Pasteur's observations that proteins could be synthesized by yeasts from inorganic nitrogen, including ammonium salts. The fact that yeast, including brewers' yeast, contains a high percentage of protein had long been known and attempts were made to utilize the surplus quantities from brewers until the production of beer was cut by 60 percent. In 1915, Hayduck announced that he had discovered what he called "mineral yeast" as a contaminant at a pressed-yeast factory. This yeast, which is non-sporing and was afterward called *Torula utilis*, gave much better yields of protein than did other yeasts and, moreover, produced little alcohol. A yeast product was put on the market, but large-scale production apparently could not be carried on because of lack of sugar.

With the outbreak of the present war, the possibility of a shortage of protein had to be faced, and the problem was allotted to A. C. Thaysen and his colleagues at the Chemical Research Laboratory. Eventually they decided that *Torula (Torulopsis) utilis* was most likely to prove satisfactory. As the situation developed, it was realized that the postwar feeding of ravaged Europe would be one of the major problems, and that for some time vitamin B deficiency would be an additional danger. An analysis of dried *Torula utilis* showed that, as well as 45 to 50 percent of a protein only slightly less nutritive than a good animal protein, this "food yeast" contains the whole known range of water-soluble B vitamins. Further, it mixes readily with water and with milk and can be used in all sorts of ways. Large-scale manufacture is to be carried out in Jamaica where molasses is abundant—200 gm. of molasses give 50 to 60 gm. of food yeast. The Colonial Development Fund has granted £150,000 for the erection of the plant and it is estimated that food yeast can be marketed at 6d. per pound. Many other parts of the Empire are considering erecting plants for the benefit of the local population. It is understood that in Germany the yeast is again being used with hydrolyzed wood as the source of sugar.

At Teddington, a strain of *T. utilis* was developed which will grow better at tropical temperatures than would the normal form. It gives a quicker yield and has less variability in size. Later, a giant strain (v. *major*) was produced by acting on the cells with camphor: the biochemical activities are identical, the variety is stable, its cells are more readily separable and its generative time is considerably less.

Another observation by Pasteur was that in ordinary yeast fermentation a small percentage of glycerine is always produced. During

the War of 1914–18, the Germans were short of glycerol for making explosives. Neuberg, in 1911, had begun to publish his studies on the stages leading to alcohol formation by yeast. When experimenting on aldehyde fixation with sodium sulphite, there was a large increase in the percentage of glycerol. Connstein and Lüdecke successfully applied this to large-scale production; many will remember the wild guesses that were made at the time concerning the source of the enemy's glycerine. They produced 1,000 tons a month by the method, the average yield being 20 to 25 percent of the sugar used, and in addition large quantities of alcohol and acetaldehyde were obtained as byproducts. It has been said that it enabled the Germans to carry on the war for another 12 months. The Americans, hearing that glycerine was being produced by yeasts, succeeded in devising a couple of similar processes. H. Raistrick and his colleagues, after 1918, used a modified sulphite process at Nobel's factory at Ardeer and increased the yields of glycerine in the fermentation liquor to 35 to 40 percent of the weight of sugar fermented. Subsequent improvements in the methods of recovery of glycerine from the fermentation liquors have reduced the cost of fermentation glycerine to a figure comparable with that of soap lye glycerine.

One of Pasteur's statements, "We are convinced that a day will come when molds will be utilized in certain industrial operations, on account of their power of destroying organic matter",³ in spite of its definiteness, was generally disregarded. However, his favorite pupil, van Tieghem, established the importance of molds in the biochemical field. He investigated the method of production of gallic acid from heaps of vegetable matter containing tannin—gall nuts, sumach, tea, etc.—watered and allowed to go moldy. He showed in 1867 that the mold principally concerned is *Aspergillus niger*. The present-day method of production is to inoculate clear tannin extract with this fungus.

It was not until 1893 that the first real advance was made, when Wehmer described the production of citric acid by two species of *Penicillium* (*Citromyces*) grown in nutrient sucrose solutions containing calcium carbonate. It has been found that a number of molds produce citric acid, but the one used on a commercial scale is *Aspergillus niger*. In 1922, Italy produced about 90 percent of the world's supply of calcium citrate from citrous juices, but within 8 years the export had practically stopped because of the commercial production by molds—10,000,000 pounds annually in the United States alone. There is now an International Citric Acid Agreement.

The process is a surface fermentation of a nutrient sucrose solution, with a comparatively large amount of mineral acid which prevents the growth of bacteria and most molds. The solution is seeded with

³ Pasteur, L., Studies on fermentation. English translation, p. 261, 1879. I am indebted to Dr. J. Yuill for directing my attention to this.

spores of *Aspergillus niger*, and as these germinate the surface becomes covered with a frail pellicle which rapidly develops and, by the end of the fermentation (8 to 12 days), becomes a fairly thick and deeply intricately folded mat but still quite white. Most of the sugar has by then disappeared from the solution, its place being taken by citric acid practically unaccompanied by other organic acids: the solution is much more acid than good lemon juice. Some of the sugar, however, is converted into fungus starch and some into dextrin. The standard way to recover the citric acid from the fermented liquor is to add milk of lime and heat nearly to boiling point, then filter off the difficultly soluble calcium citrate and wash with hot water.

Another process in which *Aspergillus niger* is used is the production of gluconic acid, the calcium salt of which is of importance in pharmacy. Here the best results are obtained from well-aerated submerged growth, which is most economically accomplished by using rotatory drums.

Molds are able to build up their normal cell constituents from an amazingly large and varied series of carbon compounds. Moreover, as seen with *Aspergillus niger*, the same species of mold, when growing in slightly different conditions, can produce different substances. Citric acid, oxalic acid, gluconic acid, ethyl alcohol, and mannitol, which may be regarded as the break-down products of the original sugars, are formed by many species.

There are, however, many substances which are built up by mold growth, and for the most part these are highly specific products of a single species, or of a few related species. The chief worker in this field has been Raistrick, who, following on his work on glycerol production, has been engaged with numerous collaborators in investigating the general biochemistry of molds. The scheme followed has been to use glucose as the sole source of carbon in a synthetic culture medium—usually Czapek-Dox medium. In this long-continued and productive research, about a hundred substances previously unknown to science have been prepared and many of them synthesized. It may well be that some of these will be found useful in some way or other, but their present interest is chiefly in giving us a picture of what happens inside the cell. Mold pigments, simple quinones, polyhydroxy-anthraquinones and hydroxyxanthenes, simple benzene compounds, chlorine-containing metabolic products, derivatives of tetronic acid (stimulants of bacterial growth), antibacterial and antifungal substances are included in the products.⁴ It is a matter of phylogenetic interest that the lichen acid physcion (parietin) is formed by 16 species or strains in the *Aspergillus glaucus* series.

⁴ A wide range of these special chemical compounds was exhibited.

To understand the magnitude of work of this kind one has to take into consideration that in a given species there are strains some of which are more active, some less; further, that the results differ according to the chemical constitution of the medium and the physical conditions of growth.

Ever since fungi and bacteria were grown on artificial media, it has been observed that in mixed cultures one organism may have no apparent effect on the growth of the other, or it may influence it either favorably or unfavorably. This favorable effect (synergism) may be considered as an aspect of symbiosis; the unfavorable (antagonism) as an aspect of the struggle for existence.

Antagonism is gradually becoming recognized as a factor in plant disease. The fungi which abound in the soil include some species which are able to become parasites and cause destructive root rots. Chemical and physical conditions of the soil determine the amount of a given species, but they also act on the other fungi present, one or more of which may have an antagonistic reaction toward the parasite. Thus the mold *Trichoderma viride*, common in the soil, has an antagonistic effect on the growth of the tree parasite *Armillaria mellea*.

The phenomenon of antagonism has been brought strikingly to public notice following an observation by A. Fleming in 1928. When studying the growth of *Staphylococcus* on solid media in Petri dishes, he noticed that the colonies underwent lysis in a zone surrounding a growth of *Penicillium* which contaminated one of his cultures. He grew the *Penicillium* in broth culture, and found that the filtrate was some two or three times as effective as pure carbolic acid in stopping the growth of *Staphylococcus*.

For convenience the name "penicillin" was used in place of the rather cumbersome phrase "mold-broth filtrate." Fleming showed that penicillin had a specific action on certain bacteria (*Staphylococcus*, *Streptococcus*, *Pneumococcus*, *Gonococcus* and the diphtheria bacillus), but that others (*B. coli* and *B. influenza*) were not affected. The first practical application of penicillin was the isolation of the insensitive Pfeiffer's bacillus, which in the respiratory tract is usually associated with organisms highly sensitive to penicillin. But Fleming also stated that penicillin had no poisonous effect and that "it may be an efficient antiseptic for application to, or injection with, areas infected with penicillin-sensitive microbes." In 1931, he prophesied that "it is quite likely that it, or a chemical of a similar nature, will be used in the treatment of septic wounds." In the following year Raistrick and his collaborators grew the *Penicillium* (which Thom identified as *P. notatum*) in a synthetic medium consisting solely of glucose and inorganic salts, and defined the optimum conditions of

growth. They acidified the medium slightly, extracted with ether, and on removal of the ether obtained the antibacterial substance in a crude form and to it restricted the name "penicillin." It was found to be extremely labile. A very definite step had been taken⁵ and sulfonamides were not yet discovered. It remained for H. W. Florey and his collaborators to reveal the outstanding therapeutic properties of penicillin. Florey worked first with lysozyme, another of Fleming's discoveries, and in the search for other antibacterial substances produced by micro-organisms, E. Chain and Florey turned their attention to penicillin. A culture of Fleming's fungus was obtained and the penicillin was extracted with amyl acetate. Shaking out the amyl acetate with a buffer solution and evaporating the buffer solution gave a substance which was at first thought to be pure penicillin because it proved to be so active. The results of the clinical trials published in 1940 showed that it possesses unique therapeutic properties which, moreover, because of its nontoxicity, make it of outstanding value in the treatment of war wounds. But the penicillin used in these chemical experiments was only about 1 percent pure. Several workers here and in the United States are engaged on research in purifying penicillin; a crystalline sodium salt has been obtained which is a hundred times more active than the first extractions. It is capable of inhibiting the growth of certain bacteria at a dilution of about 1:50,000,000. Penicillin is a complex acid of which the exact structure is not yet known.

[When the first trials had shown that penicillin was likely to prove of enormous value in the treatment of war wounds, the problem was to obtain the necessary amount. Florey, in the autumn of 1940, urged the United States to take up the production and, whatever the reason for this, it is certain that no such effort as that of American scientists and manufacturers could have been made here at that period. New strains of *Penicillium notatum* were sought for, new media devised, and additional therapeutic trials were carried out. Production was eventually such that all the needs of the fighting forces could be met. Over 90 percent of the penicillin used during the war was of American origin. Very extensive research on the structure of penicillin has been carried out both here and in the United States, but although more than one kind of penicillin has been mentioned, the complicated chemistry of this remarkable substance still remains to be revealed.]

Until recently, all the *Penicillium notatum* used, both in the laboratory and in large-scale manufacture, was from Fleming's original

⁵ "Another point which shows what practical results may be expected from such research is that penicillin, a metabolism product of *Penicillium notatum*, is nonirritant and nontoxic, but has a strong though different antibacterial power." Presidential address to Section K of the British Association, Ann. Rep. British Assoc., 1936, p. 215.

isolation. It was indeed a strange chance which led to the contamination of a laboratory culture by an apparently uncommon mold (originally described from decaying hyssop in Norway); and that the laboratory should be that of one who was curious in antibiotic phenomena and who, convinced of the value of his discovery, kept not only the original plate but also maintained the mold in culture. Further, it was fortunate that the original Oxford isolation of crude penicillin contained little if any toxic substances, with the result that Florey and the Oxford team were so soon able to announce almost undreamed-of achievements. This general freedom from association with harmful products incidentally has also characterized home-grown cultures of penicillin.

Penicillin is the most active bacteriostatic substance so far known; but the difficulty of obtaining sufficient quantities and its unstable quality have led to the search for similar mold products, and has also stimulated general research. There are many such products known, but few are sufficiently nontoxic for use. Flavicin from *Aspergillus flavus* and gigantic acid from *A. giganteus* are most similar to penicillin in their chemical and biological properties.

Raistrick and his colleagues have tested many of the compounds they had isolated and all new substances which were obtained. The product of the fermentation of *Penicillium patulum* (originally isolated from sheep dung in France) was considered promising and was sent to W. E. Gye, who is studying the effects of various substances on cancer cells. As he was suffering from a cold, he used it on himself with most satisfactory results. Extended trials show that it is able to cure a promising number of cases of one form of the common cold. It has since been shown that patulin is identical with clavacin and clavatin obtained from *Aspergillus clavatus*, and claviformin, from *Penicillium claviforme* and *Aspergillus giganteus*. It is not surprising that the same chemical substance should be formed by several fungi—indeed, this is what one would expect. What is of greater interest is that it is also produced by *Penicillium expansum*. Van Luijk in 1938, studying the diseases of grasses caused by species of *Pythium*, found a difference in plants grown in sterilized and non-sterilized soil. He isolated a number of fungi from the soil and from the air and tested their influence on the growth of *Pythium*. He found that *Penicillium expansum* was the most markedly antibiotic, and adopting Fleming's procedure, obtained sterilized filtrates: these inhibited the growth of *Pythium debaryanum* at dilutions of 1:1,280. He did not isolate the antifungal substance, which Anslow, Raistrick, and G. Smith (1943) have shown to be patulin. When the fungus was added to garden soil infected with *Pythium*, seedlings remained healthy instead of damping off.

Here we seem to have a linking up of different lines of research in such a way that we may expect considerable progress. The recognition of the chemical constitution of a substance produced by a common soil fungus which suppresses the growth of a plant pathogen suggests that greater precision may soon be given to many of the older observations on fungal antagonism of various kinds. Incidentally, it may also have some bearing on the question of natural compost versus chemical fertilizers. There is a difficulty in establishing the growth of antagonistic organisms in the soil; this can be done only by modifying the conditions, and an obvious way to do this is to add manure or compost which favor fungal growth. That the matter is not quite so simple as it appears at first sight, however, may be judged from the fact that Barnum in 1924 showed that the filtrate of cultures of *Penicillium expansum* caused wilting in certain herbaceous plants placed in it.

No more than mention can be made of the production by fungi of fats, ethyl alcohol, lactic acid, vitamins, and enzymes, or of the immense fermentation industries of the Orient.

THE INTRODUCTION OF ABACÁ (MANILA HEMP) INTO THE WESTERN HEMISPHERE¹

By H. T. EDWARDS

Principal Technologist, U. S. Department of Agriculture

[With 10 plates]

The story of plant exploration and introduction furnishes material for one of the most interesting chapters in the history of world agriculture. For centuries, explorers and scientists have collected and brought back to their home countries seeds and plants from foreign lands. The purpose of this work has ordinarily been to obtain plant material that might be utilized either for the improvement of agricultural industries already established, or, in some instances, for the establishment of entirely new industries.

Many of the details relating to seed and plant introduction projects have never been recorded, and the history of this work will never be written in its entirety. The value of any one particular plant introduction, or the ultimate effect which such an introduction may have had in relation to the development of agriculture can never be fully determined. In some instances the dollars-and-cents value of a new plant or a new industry may be approximately estimated. There are other cases in which the fact that a plant product has been available at a time when it was urgently needed was a matter of far greater importance than its monetary value. Under the emergency conditions which exist during a world war there are certain "critical" or "strategic" materials which must be obtained, if possible, with but little consideration of their cost. Abacá fiber, which furnishes the raw material for certain manufactured products required in military operations, is an outstanding example of a "strategic" plant product.

This fiber, which is known in the Philippine Islands as abacá and in trade circles as Manila hemp, is used for the manufacture of so-called

¹ EDITOR'S NOTE.—Readers of this paper will be interested to know that the author has omitted one important detail: it was Harry T. Edwards himself who anticipated during World War I future wartime interferences with abacá importations, advocated production in tropical America, personally made the shipment of living plants from Davao to Panama and then followed up the project until his retirement in 1945, when the results of his work were apparent in the substantial quantities of abacá made available.

Manila rope. It is the product of a plant that resembles in appearance the common banana plant to which it is closely related, and is an exceptionally strong and light material that is highly resistant to the action of salt water. More than a century ago the discovery was made that for making strong and durable cordage, and particularly marine rope, there is no other plant fiber in the world obtainable in commercial quantities that is equal in quality to abacá. The use of this fiber was established in Massachusetts about 1820, and Manila rope soon became standard equipment on every ship that sailed the Seven Seas. At the time of the entry of the United States in World War II no entirely satisfactory substitute for abacá was obtainable, the entire supply of this fiber had been cut off by the Japanese occupation of the Philippine Islands and the Netherlands Indies, and the requirements of the war effort necessitated an immediate increase in the production of many different types of abacá cordage. Fortunately, the introduction of abacá into Tropical America had provided in part for an emergency of this character. Many years before the outbreak of the war abacá plants had been brought to Panama by the United States Department of Agriculture. Preliminary experimental work had been completed by an American plantation company, and a large supply of planting material was available. It was possible, therefore, to start immediately the large commercial plantings of abacá in Central America that by 1945 had furnished more than 20 million pounds of this urgently needed rope fiber—a quantity of fiber sufficient for the manufacture of more than 3,000 miles of 6-inch rope.

THE PANAMA ABACÁ PROJECT

During World War I persons familiar with the world fiber situation, and also with conditions in the Orient, had seen an element of danger in having the production of the entire world supply of abacá fiber confined to limited areas in islands of the western Pacific, principally the Philippines. It was clearly evident that in the event of a world war in which these islands might be occupied by enemy forces, and the Pacific sea lanes even partially closed, the United States' one source of supply of this essential raw material would be entirely eliminated. This theoretical situation became an actuality at the time of Pearl Harbor. Furthermore, there had been the definite possibility that the continued spread of diseases of the abacá plant, which had already destroyed relatively large areas of abacá in the Philippines, might result in the near future in a decreasing production of Philippine abacá fiber. With the exception of the Province of Davao, where the growing of abacá was efficiently conducted by Japanese plantation companies, there had been for some years a declining production of this fiber throughout the Philippine Islands.

Investigations of this situation, made by fiber specialists of the United States Department of Agriculture, led to the conclusion that studies should be made of the practicability of introducing abacá into Tropical America. At that time there was no general understanding of this problem, the then future happenings of World War II seemed unlikely to occur, and the advisability of attempting to bring abacá to the Western Hemisphere was questioned. The introduction was made, however, and in 1925 abacá plants were brought from the Philippine Islands to the Republic of Panama and the so-called Panama Abacá Project was established. For many years there was no marked change in the situation in the Orient, supplies of Philippine abacá fiber continued to be available, and this project in Panama led a somewhat precarious existence. At times it was almost abandoned, but abacá is a hardy plant and the few plants that had been brought to Panama continued to live. The few persons who were interested in this project continued to believe that in course of time there would be need for Western Hemisphere abacá. That time arrived on December 7, 1941, and 6 days after Pearl Harbor the commercial development of abacá production in Central America was actively under way.

FIBER NOMENCLATURE

The term "hemp" has become in the fiber industry almost a synonym for the word "fiber." In numerous instances fibers entirely different in type and obtained from plants having no close botanical relationship are known as hemp. In the fiber trade these many different hems are distinguished by the name of some town or city from which they are, or have been, exported. Sisal hemp, for example, is not hemp and is no longer exported from the port of Sisal in Yucatan. This situation has resulted in confusion and in many errors in statistical data. The fiber that is commonly known as Manila hemp or Manila fiber is not hemp, and relatively small quantities of this fiber are now shipped from Manila. The word "abacá," which is of Malay origin, is used in the Philippines to designate this fiber and also the plant from which it is obtained. The increasing production of abacá fiber in countries other than the Philippine Islands has led to a more general use of the word "abacá," and it appears probable that this fiber, when produced in the Western Hemisphere, will be known both in the trade and elsewhere as abacá fiber.

THE ABACÁ PLANT

The abacá plant, *Musa textilis*, is a perennial growing from short rootstocks. A mature abacá plant or "mat" consists of a group of stalks from 6 to 15 feet in height, which are formed by the broad over-

lapping leaf stems and which bear at the top large spreading leaf blades from 3 to 6 feet long and about 12 inches wide. The fiber is obtained from the outer portion of each successive leaf stem. The color of the stalk ranges in the different varieties from a light green to dark purple or nearly black. When mature, a flower stalk about 2 inches in diameter is pushed up through the center of the abacá stalk, bearing at the top flowers which are followed by green fruits similar to small bananas but filled with black seeds. Abacá plants grown from seeds ordinarily do not come true to type, and the usual method of propagation is by the use of rootstocks or suckers. Abacá requires a warm, moist, tropical climate, and a deep, fertile, and well-drained soil.

ABACÁ FIBER

In the classification of fibers, abacá is included in the group of so-called hard fibers, which are obtained from the leaves and leaf stems of plants. Abacá is a multicelled long fiber consisting of cylindrical strands of fibrovascular bundles. Philippine abacá fiber of "excellent" cleaning is ordinarily from 6 to 12 feet in length, white to light ochre in color, lustrous, strong, and of clean, even texture. Western Hemisphere abacá fiber, which will be machine-cleaned, will range in length from 4 to 6 feet and will be somewhat less uniform in color than the Philippine fiber. It will have, however, the same basic qualities of exceptional strength and resistance to the action of salt water that are characteristic of Philippine abacá. The combination of strength, durability, and water resistance makes abacá the most valuable known fiber for marine cordage. It is also extensively used for transmission and hoisting rope, well-drilling cordage, and for many other purposes where exceptional strength and durability are required.

HISTORICAL BACKGROUND

The documents of the Venetian, Antonio Pigafetta, who was one of the companions of Magellan in the first circumnavigation of the globe, include a description of the Island of Zubu (Cebu). This is followed by a list of "Words of those heathen people," which includes the following: "For the cloth with which they cover themselves—Abacá." In 1686 Capt. William Dampier, an Englishman, visited the Island of Mindanao, and the records of this voyage contain a description of the production and use of "plantain" fiber. There is also a reference to plaintains of another variety, possibly abacá, on that island which are full of black seeds. There are occasional references to the use of abacá fiber by the Spaniards in the Philippines during the seventeenth and eighteenth centuries, and in 1820 a sample of abacá fiber was brought to Salem, Mass., by John White, a lieutenant in the United

States Navy. After 1824 this fiber began to be used very extensively in Salem and Boston. Apparently the first commercial shipment of abacá from the Philippines was 41 tons exported in 1818. The exports increased to 276 tons in 1825, and 8,561 tons in 1850. Fifty years later, in 1900, abacá exports from the Philippines were 89,438 tons. From 1900 to 1908 abacá represented more than 60 percent of the total value of all Philippine exports.

ABACÁ IN THE PHILIPPINE ISLANDS

Abacá fiber is produced in the Philippines under a wide range of conditions. In the hill country of southern Luzon, the Visayan Islands, and northern Mindanao, there are thousands of Filipino farmers who have small plantings of abacá and who clean the fiber with the crude stripping knives that probably were used centuries ago. When abacá is planted under these conditions, a small area of forest land is cleared and the rootstocks or suckers are set out in holes that have been dug with a bolo (machete). There is no cultivation except a partial cutting down of shrubs and grass when the abacá is harvested. The crop is harvested irregularly and at the convenience of the owner. The fiber is cleaned with the antiquated hand-stripping apparatus, dried in the sun, and ordinarily is sold to a local Chinese middleman. As there is no uniformity in the stripping knives, large quantities of fiber of inferior quality are produced.

During the period of Spanish occupation of the Philippines fairly large abacá plantations were established. The methods used on these plantations, although an improvement on the native cultivation, were relatively primitive. Abacá was planted in rows, but essentially the same method of planting was used. The periods of harvesting were more regular, but there was no cultivation of the fields and the fiber was cleaned by hand-stripping. For the work of stripping the fiber and clearing the fields, the workers usually received approximately one-half of the product. The owners of these plantations were familiar with market conditions, and more attention was given to the production of fiber of good quality.

In 1904, a few years after American occupation of the Philippines, an agricultural survey was made of the District of Davao in southern Mindanao and the information obtained by this survey was published. At that time large areas of unoccupied government land were available in Davao, and the climatic and soil conditions of this region were exceptionally favorable for abacá. Several small abacá plantation companies were organized in Manila, and a number of Americans went to Davao for the purpose of establishing abacá plantations. This development marked the beginning of a new era in the production of abacá. The American planters, realizing the imperfections in the

old abacá industry, began to investigate and experiment. The different varieties of abacá were studied and the superior varieties were used in these new plantings. New systems of planting were introduced and the "camotes" (sweetpotatoes) which had formerly been planted in the abacá fields were replaced with legumes. These and many other improvements resulted in yields of abacá that were regarded as impossible by the old abacá planters in the northern islands, and in a quality of fiber that soon attracted the attention of manufacturers in foreign countries. At that time there was a shortage of labor in Davao, and it was extremely difficult to obtain the large number of laborers required for stripping the fiber. For many years numerous unsuccessful attempts had been made to perfect a machine for cleaning abacá fiber, but it was not until about 1921 that the so-called Hagotan and Universal machines were placed on the market by an American firm in Manila. These machines, which are a modified and improved form of the old hand-stripping method, were promptly adopted by the Davao planters, and by 1941 practically all the abacá fiber produced in Davao was cleaned with these machines.

Some years after the establishment of American abacá plantations in Davao, a Japanese businessman, a Mr. Ohta, came to Davao from Manila. A Japanese abacá plantation company was organized, and from that time onward there was a steady and rapid growth of Japanese interests in the Davao abacá industry. The Japanese plantation companies apparently had abundant capital and were able to bring laborers to Davao from Japan. Large areas of government land were leased to the Japanese, and two or three large holding companies controlled the operations of numerous smaller companies. The Japanese Davao Planters' Association effectively coordinated all the efforts of the Japanese in Davao. The investigational work, which had been started by the American planters in Davao, was expanded and improved by the Japanese. Scientists were brought to Davao from Japan, and experiment stations and laboratories were established. The net result of these operations was that at the time of the entry of the United States in World War II the Province of Davao was producing approximately one-half of the entire output of Philippine abacá fiber, and something like 85 percent of the entire Davao production was controlled by the Japanese.

EARLIER ABACÁ INTRODUCTIONS

Complete records of the attempts that have been made to grow abacá in countries other than the Philippines are not available, but many such attempts have been made. With but few exceptions these experiments were unsuccessful, and in consequence many persons

familiar with abacá were of the opinion that this plant could be grown successfully only in the Philippine Islands. As abacá can be propagated from seeds, and as the seeds are readily available and easily transported, it is probable that this method of propagation was used in most of this experimental work. The fact that abacá usually does not come true to type when grown from seeds was either unknown or failed to receive consideration. There are reports of abacá introductions into India, the Andaman Islands, New Guinea, the Federated Malay States, Ceylon, Fiji, the Solomon Islands, and the West Indies, but the commercial production of abacá fiber did not become an established industry in any of these countries.

A short time after American occupation of the Philippine Islands the Office of Fiber Plant Investigations of the United States Department of Agriculture attempted the introduction of abacá into the United States. In April 1901, a consignment of seeds of four different varieties of abacá was received in Washington from an abacá planter in the Island of Negros. These seeds were planted in the Department greenhouses in Washington and also in Florida, but none of them germinated. Early in 1902 abacá seeds that had been received from the Philippine Bureau of Agriculture were sent to Puerto Rico for planting, but none of these seeds germinated. In October 1902, a second lot of seeds received from the Philippine Bureau of Agriculture were planted in Washington and 89 seedling plants were obtained. These plants were distributed early in 1903 to Jamaica, Trinidad, Puerto Rico, the Hawaiian Islands, and Florida. It was subsequently reported that the plants sent to Puerto Rico and Florida were growing well, but apparently they ultimately disappeared.

This introduction work was continued, but from six different lots of Philippine abacá seed received in Washington during the period from 1904 until early 1911 not a single plant was obtained. In March 1911, abacá seeds of the Maguindanao variety, which had been carefully packed in charcoal in tin mailing tubes, were received from the Philippine Bureau of Agriculture. These seeds were planted in the Department greenhouses in Washington, and from this planting about 1,200 seedlings were obtained. A distribution of these plants was made to Cuba, Puerto Rico, Nicaragua, Costa Rica, Panama, Mexico, and the Hawaiian Islands. It appears that with one or two possible exceptions all these plants were later destroyed or abandoned. Abacá plants now growing at the Agricultural Experiment Station, Mayaguez, P. R., are said to have come from this distribution. In 1925, two or three "mats" of old abacá plants of the Maguindanao type were found in a somewhat isolated place near Almirante, Panama, and it is possible that these plants came from the introduction of Maguindanao seedlings made in 1912.

TWENTY YEARS BEFORE WORLD WAR II

The occupation of the Philippine Islands and the Netherlands East Indies by the Japanese early in 1942 eliminated for the time being, insofar as the Western Hemisphere was concerned, the entire world supply of abacá fiber. In view of the happenings of this period, it is of interest to observe the manner in which this situation was foreseen 20 years earlier by a fiber specialist in the United States Department of Agriculture. The following statements relating to this subject are portions of an official government memorandum prepared in November 1921:

The problem of establishing the production of abacá on a commercial scale in Tropical America is one that has been considered for many years. With the changes that are taking place in the industrial situation in the Philippine Islands, and with the uncertain political status of that country, this problem of making adequate provisions for an assured future supply of abacá fiber is one that must sooner or later receive attention. During the past 2 years I have had occasion at different times to discuss this subject with several of the prominent cordage manufacturers in this country. These men regard the present abacá situation with considerable apprehension, and strongly urge that an attempt be made to establish a source of supply of this fiber in Tropical America.

The existing abacá situation.—The average annual consumption of abacá fiber in the United States for the past 12 years has been approximately 72,000 tons. This amount is about one-half the total world production of this fiber. The principal uses of abacá fiber in the United States are for the manufacture of the best grades of marine cordage, well-drilling cables, and transmission rope. This fiber is also used for a great variety of other purposes, including the manufacture of binder twine and various kinds of cordage. For purposes where exceptional strength, a marked degree of elasticity, or resistance to the action of salt water are required, there is no other known fiber that is a satisfactory substitute for abacá. An adequate supply of abacá fiber is essential to the continued operation of the American cordage industry. An adequate supply of Manila rope is a highly important factor in the maintenance of the United States Navy and the merchant marine, in the production of mineral oil, in the construction of buildings, and in many other industries. The entire world supply of abacá fiber, with the exception of a few hundred bales, is now produced in the Philippine Islands. During the past 3 years 99.5 percent of the total supply of abacá fiber consumed in the United States has been obtained by direct shipment from the Philippine Islands.

Elements of danger in this situation.—The existing abacá situation is a striking instance of having "all of our eggs in one basket," with that basket on the opposite side of the world, and with no action being taken to remedy or even modify these conditions. The essential elements of danger in this situation are as follows:

1. In the event of war with any nation having a strong navy, the United States would presumably lose control of the Philippine Islands for a considerable period of time, and its supply of abacá would be entirely cut off at a time when there would be urgent need for an abundant supply of this fiber.

2. When the United States relinquishes political control of the Philippine Islands, our future supply of abacá will be highly uncertain. It is a fact of no small significance that the Japanese within the past few years, have obtained

control of a large part of the abacá holdings in the District of Davao, which leads all provinces in the Philippines in the production of the best grades of cordage fiber used in the United States. It is also of interest to note that the Chinese control a large portion of the trade in abacá.

3. The Government of the Philippine Islands has but limited facilities for eradicating, or even controlling plant diseases. Within recent years diseases of abacá have been causing an increasing loss, and as the production of abacá is confined to a limited number of provinces and islands one of these diseases might easily spread throughout the entire abacá-producing area. The fate of coffee, coconuts, and bananas in certain regions of the Tropics shows very clearly what may happen at any time to abacá in the Philippine Islands.

The logical remedy.—If it is admitted that there is an element of danger in the United States' being dependent on the Philippine Islands for its entire supply of abacá fiber, the logical remedy for this situation is to establish a source of supply of this fiber in some country other than the Philippines. While abacá has never been produced on a commercial scale in Tropical America, there appears to be no reason why such production is not practicable. The climatic and soil conditions in portions of Panama, in certain other parts of Central America, and in the Vega Real of Santo Domingo are quite similar to the conditions found in the abacá provinces of the Philippine Islands. It is known that abacá has made a luxuriant growth in Panama, and that certain species or varieties of *Musa*, producing fiber of fairly good quality, are now being grown in the Vega Real region. With the adoption in the District of Davao in the Philippine Islands of a simple, but fairly satisfactory, machine for cleaning abacá, and with the progress that has been made during the past year with other machines for cleaning this fiber, there is every reason to believe that abacá produced in Tropical America could be cleaned with machines.

Procedure recommended.—As the results thus far obtained in propagating abacá from seeds have been generally unsatisfactory, it is believed that the establishment of this industry on a commercial basis in Tropical America will involve the importation from the Philippine Islands of suckers of several of the best varieties of abacá. Before making any definite arrangements for the importation of abacá suckers, it would be advisable to obtain detailed and accurate data regarding the climatic and soil conditions, areas available for abacá planting, attitude of the local planters toward this project, and any other useful information pertaining to the localities where it is proposed to plant abacá. It is recommended that such an investigation be made, which would serve as a basis for future work.

The recommendation that a preliminary investigation be made of conditions in the Canal Zone and the Republic of Panama was approved in December 1921. This was the beginning of the project that made it possible on December 12, 1941, 5 days after Pearl Harbor, for representatives of the Government, the United Fruit Co., and the cordage manufacturers to meet in conference in Washington, and by the following week to have the commercial development of the abacá projects in Central America actively under way. The history of the whole project is one of many difficulties and some failures but ultimate success.

ABACÁ IN CENTRAL AMERICA

Unlike some of the other hard-fiber crops, abacá is rather exacting in its climatic and soil requirements. An abundant but not excessive

supply of moisture and a fertile, well-drained soil are essential to the normal development of this plant. In considering, in 1921, the introduction of abacá into Tropical America, it was necessary to determine not only where nurseries might be established but also where the conditions were favorable for subsequent plantation development, and for the purpose of obtaining this information preliminary surveys were made in the Canal Zone and in certain regions of the Republic of Panama. It was found that on the Pacific side of the Canal Zone and in adjoining areas in Panama the climatic conditions are unfavorable for abacá because of the long dry season. On the Atlantic side of the Canal Zone there are small areas where abacá nurseries might have been established, but these areas were too small for plantation operations and the topographical conditions were unfavorable. In the production of abacá under a system where the stalks are moved from the fields to a central cleaning plant about 96 percent of the material transported is waste. In a rough hilly country the transportation costs are excessive, and it is not practicable to operate large plantations under these conditions.

In the Province of Bocas del Toro in the Republic of Panama, which adjoins southern Costa Rica and is about 160 miles west of the Atlantic end of the Panama Canal, a large estate of the United Fruit Co. extends inland from the town of Almirante. As experimental work with so-called abacá had been conducted at this place during 1920 and 1921, an investigation was made of conditions at Almirante. On arrival at Almirante it was learned that small quantities of fiber had recently been produced and submitted to a firm of fiber merchants in New York for examination. It was reported that this fiber was greatly inferior to Philippine abacá, and the opinion was expressed that this was another demonstration that abacá fiber of satisfactory quality could be produced only in the Philippine Islands. Samples of this fiber were examined and it was found that insofar as quality was concerned the New York report was correct. It developed, however, when the plants from which this fiber had been obtained were inspected that these plants were a type that is sometimes referred to as "bastard" abacá, and possibly were the progeny of seedling plants that were sent to this region many years ago. These same plants, had they been grown in the Philippine Islands, would have produced fiber no better in quality than that which was obtained at Almirante.

The natural conditions of this region are rather similar to the conditions found in the Province of Davao, which is the leading abacá province in the Philippine Islands. A heavy and relatively well-distributed rainfall, and a fertile, well-drained soil are the basic requirements of this plant. Furthermore, large areas of abandoned banana lands on which abacá might be grown were available on this

estate. As abacá is a close relative of the banana plant, and as practically all the bananas at Almirante had been destroyed by the virulent "Panama" disease, the disease situation was threatening, but it seemed unlikely that any location for experimental work with abacá could be obtained in Central America that would be entirely free of this disease. As the management at Almirante was definitely interested in the project and offered to cooperate in any experimental work that might be undertaken, it seemed advisable to make tentative arrangements for the establishment of an abacá nursery at this place. The next step in the project was to obtain from the Philippine Islands the plant material required.

OPPOSITION IN THE PHILIPPINES

There were both political and business interests in the Philippine Islands opposed to the exportation of abacá plant material. When it became known that consideration was being given to experiments with abacá in Panama, the three chambers of commerce in Manila, including the American Chamber of Commerce, presented a joint resolution to the Governor General requesting that the exportation of abacá plant material to any regions other than the United States and its possessions be prohibited. The Director of Agriculture in the Philippines, in an exceptionally strong and logical statement, advised against the enactment of any legislation of this character, and for the time being no further official action was taken. The agitation continued, however, and finally resulted in the enactment by the Seventh Philippine Legislature of a law prohibiting the exportation from the Philippine Islands to foreign countries of seeds of abacá and its derivatives. This law was approved by the Governor General on December 1, 1925, but fortunately some 3 months earlier a large consignment of abacá plants that proved successful had been shipped from Davao to Panama.

INTRODUCTION OF 1923

Early in 1923 an unsuccessful collection of about 350 rhizomes of four varieties of abacá had been obtained in Davao. These plants were dug on the plantations in Davao early in March, and received rough handling on the small interisland boat during the period of shipment from Davao to Manila. They were received in Manila during the middle of the hot season when conditions were unfavorable for the transportation of material of this character. The rhizomes were dipped in a lime sulfur solution under the supervision of a government plant pathologist, inspected by the plant inspectors, repacked, and shipped to the Canal Zone. Seven weeks elapsed from the time the plants left Manila until they arrived in the Canal

Zone where they were taken to the Plant Introduction Gardens at Summit. On examination it was found that all the plants were dead, that they contained large numbers of active nematodes, and that there were indications of root borers. On being advised of the condition of this shipment, the United Fruit Co. issued instructions that no further abacá plant material from the Philippines would be received, and that they would not be in a position to conduct any further experiments with abacá.

INTRODUCTION OF 1924

In view of these circumstances it was considered inadvisable to attempt for the time being any more direct shipments of abacá plant material from the Philippines to the Canal Zone or Panama. It was thought, however, that a few small sucker plants might be brought to the United States and grown in the greenhouses of the Department of Agriculture at Glenn Dale, Md. In May 1924, about 25 small abacá suckers were collected in Albay Province, in the southern part of the Island of Luzon, brought to Manila, and shipped from Manila to Seattle, where they were disinfected at the plant quarantine station, repacked, and forwarded to Washington. The few plants that were still alive when they finally reached Washington ultimately died.

INTRODUCTION OF 1925

Although these experiences were somewhat discouraging, it was still believed that it was entirely practicable to obtain in the Philippine Islands "clean" abacá planting material, and to ship this material to Panama if direct transportation from Davao to the Canal Zone could be obtained and if arrangements could be made for the handling of this material after its arrival. During the latter part of 1924 it was learned that a plant pathologist of the United Fruit Co., who was familiar with conditions both in the Philippines and in Panama, would visit the Philippine Islands early in 1925 for the purpose of collecting banana plants for shipment to Panama. It was suggested that abacá plant material be collected and prepared under the supervision of this pathologist, and that a second attempt be made to make a direct shipment of abacá plants from the Philippines to the Canal Zone and Panama. This suggestion having been approved, preliminary arrangements for carrying out this project were then made in Washington. As the abacá varieties in Davao are considered to be superior to the varieties found in the northern provinces, and as this province was free, or relatively free, of abacá diseases at that time, it was planned to obtain in Davao the abacá plants for Panama.

THE TRANSPORTATION PROBLEM

In order to make direct shipment of these plants it was necessary to arrange for the routing of a ship from Davao to the Canal Zone, and this proved to be a difficult problem. It was hoped that an Army or Navy transport might be used for this purpose, but this was considered to be impracticable. The matter was finally brought to the attention of the vice president of the United States Shipping Board, who was most cooperative and offered to furnish all possible assistance. It was tentatively arranged that if sufficient commercial cargo could be obtained in Davao to cover the expense of a call at that port, a ship would be routed from Manila to the Canal Zone via Davao, and the Manila agent of the Shipping Board was instructed to furnish assistance in making necessary arrangements. One of the larger American cordage companies that had an agency in Davao agreed to furnish the required cargo, but the opposition of commercial interests in Manila together with changes in the Shipping Board agency in Manila served to complicate this situation. In the end the Shipping Board in Washington cabled the necessary instructions, and on August 20 information was received at the plantation where the plants had been collected that the S. S. *Ethan Allen* would arrive the following morning. In the meantime this large shipment of plant material had been prepared with only a fair prospect that it would ever leave the Philippine Islands.

COLLECTION AND PREPARATION OF PLANT MATERIAL

As statements had been published in the Manila press that the establishment of abacá production in Panama would ultimately ruin the Philippine abacá industry, it was somewhat questionable what might be the attitude of the Davao planters regarding this project. On arriving in Davao, conferences were held with the two leading American abacá planters, and the reasons for the project were explained in detail. No attempt was made to minimize the fact that the commercial production of abacá in Tropical America might, in course of time, adversely affect the Davao abacá industry. It is greatly to the credit of these patriotic and far-sighted men, Henry Peabody and Charles Harvey, both of whom had given the best part of their lives to the development of their plantations, that first consideration was given to the needs of their country rather than to their own personal interests. They not only offered no objections to the shipment of abacá plants from Davao, but furnished a full measure of assistance and cooperation in the work of collecting and preparing this material. Both of these men died 20 years later in Japanese prison camps, at a time when millions of pounds of marine rope, made possible because of their patriotism, were being used in the war with Japan.

Conditions in Davao were by no means ideal for work of this character. In 1925 the abacá plantations were widely separated over a large area on both sides of the Gulf of Davao, which is about 90 miles long, and there were but few miles of road in the entire province. No one of the plantations or districts had all the varieties that it was desirable to obtain, and it was essential that the collection be brought together and prepared at one place. The site finally selected for this work was the Culaman Plantation Co. in the municipality of Malita on the southwestern coast of the Gulf of Davao. A small number of plants of the varieties Libuton, Tangongan, and Sinaba, that had been collected in other localities, were sent to Malita.

On arrival at Malita a survey was made of the different areas from which it was proposed to obtain plant material. No evidence was found of abacá diseases, but in the older fields most of the abacá rhizomes were badly infested with root borers and it was evident that great care would have to be taken in the preparation of this material. This involved a careful examination of each rhizome and the cutting out of all sections where root borers were found. It was somewhat doubtful how many of the rhizomes would survive this heroic treatment, which was to be followed by the long period of storage during shipment across the Pacific. For this reason it was considered advisable to prepare a collection of growing plants. During June and July some 400 rhizomes, suckers, and buds were planted in a miscellaneous assortment of all the old oil cans and boxes that could be found on the plantation. Although more than one-half of the crated rhizomes were alive when the shipment reached Panama, the growing plants furnished the bulk of the planting material. The limited supply of packing material available on the plantation included excelsior, old newspapers, and small quantities of sphagnum and charcoal. All these materials were used in different methods of packing the rhizomes, and in addition 3 tins of seeds were packed in charcoal, and several bunches of fruit containing seeds were shipped in cold storage. The shipment when finally completed included 1,438 items of plant material, packed in 279 containers, and represented 6 different varieties of abacá.

ACROSS THE PACIFIC

Malita is an open roadstead and has no docking facilities for large ships. For several days before the arrival of the *Ethan Allen* there were indications of stormy weather, which would have entirely disrupted the plans for loading this shipment of plants. August 21 was a fine day, however, and the *Ethan Allen* arrived with a lighter in the early morning. The loading of the 190 heavy boxes and cans of growing plants from the small plantation dock to the lighter and

from the lighter to the ship, without damaging the plants, was a difficult job and it was after nightfall when this work was completed. The *Ethan Allen* sailed from Malita for the Canal Zone via Honolulu at 7:45 p. m. August 21, 1925, and 42 days later, on the morning of October 3, arrived at Balboa.

The conditions on a heavily loaded cargo ship are not favorable for the transportation of a large shipment of growing plants. The more essential requirements with respect to stowage space are good ventilation, light—sunlight if possible, protection from heavy winds and salt water, and some degree of accessibility as the plants must occasionally be watered. To obtain all these conditions in any one place on a ship, particularly during stormy weather, is practically impossible. The places available on the *Ethan Allen* for the stowage of plants were the boat deck, on top of the hatches on the after well deck, and in the poop cargo space which opens off the main deck aft. The shipment of abacá plants was divided into three parts; the boxes of plants planted in sphagnum were placed on the boat deck; the heavy boxes and cans of plants planted in dirt on the hatches, and the crates of rhizomes in the poop cargo space. This arrangement would have been satisfactory with reasonably favorable weather conditions, but as strong head winds and high seas were encountered immediately after leaving the Gulf of Davao, and as these continued throughout the greater part of the voyage, it became necessary for a time to move all the material into the poop cargo space.

Between Honolulu and Balboa it was necessary during a storm to close entirely this cargo space, leaving neither light nor ventilation. In the course of the storm some of the crates shifted and were thrown on the boxes of growing plants. As heavy seas were washing over the main deck, in spite of all precautions that could be taken a small amount of salt water entered the cargo space. It was impossible to determine to what extent this salt water reached the plants, but their condition and rapid growth during the following 2 weeks indicated that but little damage had been done. The supply of fresh water was limited, but enough was obtained for essential watering of the plants. Throughout the entire voyage not only the ship's officers, but also the members of the crew, furnished all possible assistance. On several occasions when the weather became threatening the deck crew turned out during the night to move boxes of plants or close the cargo space.

TRANSSHIPMENT OF PLANTS

On arrival at Balboa, the ship was boarded by the local representative of the Federal Horticultural Board, who accompanied the shipment through the Panama Canal to Cristobal, and from Cristobal to the plant quarantine station of the United Fruit Co. at Flat Rock on

Columbus Island. It had been intended to leave a part of this shipment in the Canal Zone, but a preliminary inspection indicated that the safest method of handling these plants would be to first take them all to the quarantine station at Flat Rock where they could be unpacked and inspected. This was done and subsequently a portion of the plants were brought back to the Plant Introduction Gardens in the Canal Zone.

In Cristobal the plants were transshipped to the S. S. *Parismina*, which sailed the following day for Bocas del Toro. On the morning of October 5, the shipment was unloaded into lighters at Bocas del Toro, was transferred to the quarantine station at Flat Rock in the afternoon, and was unloaded on the rocky beach during the late afternoon and evening. In a rough sea that was encountered during the short trip from Bocas del Toro to Columbus Island, one of the lighters broke loose from the towing launch, and a large part of the shipment was very nearly lost at this time.

CONDITIONS AT FLAT ROCK

The plant quarantine station is located in an isolated place on Columbus Island, about 6 miles by sea from the small town of Bocas del Toro. This station had been in operation only 3 months, and but little work had been done other than the construction of a relatively small plant cage. This cage furnished space for the planting of less than 15 percent of this shipment of abacá plants. As no work animals or implements other than spades were available, it was necessary to clear and spade an area outside the cage of sufficient size for planting about 800 plants. The conditions with respect to moisture were very unfavorable, and as there were no facilities for watering the plants, it was questionable how many of them might survive.

With the 8 laborers that were available 3 days were required to move the 279 heavy cases of plant material a distance of about 500 yards over a very rough trail from the beach to the plant cage. While this was being done, the work of clearing and spading the plot outside the cage was started. All the large crates and boxes were unpacked and the rhizomes were classified according to their condition as "good," "doubtful," and "bad." Of the total shipment of 1,438 plants, more than one-half appeared to be in good condition and about 73 percent were alive. The planting work was finished 5 days after the plants were landed on Columbus Island. It proved to be very fortunate that a large number of growing plants were brought from the Philippines to Panama, as many of the rhizomes that were alive when they were unpacked at Flat Rock failed to grow. Three months after this planting was made there were about 500 growing plants in the

nurseries at Flat Rock. These plants soon began to sucker freely, the nurseries became crowded, and a small field planting was made.

REMOVAL TO THE MAINLAND

In May 1926, about 8 months after the abacá was planted at the quarantine station on Columbus Island, all the plants remaining in the nurseries were removed to the mainland and a planting of approximately 1 acre was made on Farm Nine of the Almirante Division of the United Fruit Co. From the progeny of the plants grown on this 1 acre nearly 29,000 acres of abacá have since been planted in four countries of Central America.

By 1926 it was thus considered that abacá was at least temporarily established in Tropical America, and a planting of even 1 acre made possible the study of some of the problems relating to this plant and fiber. It was necessary to determine the degree of suitability of the climatic and soil conditions of this region for abacá, the resistance of this plant to diseases and insect pests, the relative value of the different varieties, the systems of planting and cultivation that might be used, and the quality of the fiber that might be produced. It was hoped that by selection and breeding, new and improved varieties of abacá might be produced. J. H. Permar, a plant breeder in the service of the United Fruit Co., who had received the abacá plants on the day of their arrival at Bocas del Toro, and who had nursed them through the critical period on Columbus Island, continued in charge of this work. For a period of about 15 years and until large commercial projects were developed, Mr. Permar directed the abacá work in Panama. Had it not been for his unbounded faith in abacá as a crop for Tropical America, together with his intelligent and persistent effort, it is very doubtful if this work would have been continued.

THE PANAMA PLANTINGS SHOW DEFINITE PROMISE

Within a year after the planting was made at Farm Nine, it became clearly evident that the climatic and soil conditions of this region are exceptionally favorable for abacá. The plants at Farm Nine, although they had not yet reached the flowering stage, were larger and more luxuriant in their growth than plants of the same age and variety grown under the most favorable conditions in the Philippine Islands. In the earlier stages of this development disease hazards gave promise of being very serious. Many of the young plants became infected with the "Panama" disease which, under similar conditions, would have completely destroyed the closely related banana plants. Fortunately, however, abacá proved to be highly resistant to this disease, which practically disappeared as the abacá became adjusted to its new environ-

ment. After a period of 18 years, although an occasional young or weak abacá plant developed "Panama" disease, the menace was not serious for the greatly needed wartime production.

A so-called Abacá Garden containing plots of all the different varieties was established at Farm Nine. Hybridization work was started in 1927 and continued through 1928. Seventy-four combinations had been made between the different varieties, and some of these new hybrids were very promising. Subsequently, during the years when the abacá project was temporarily abandoned, it became necessary to discontinue this work, but it was later resumed. A preliminary series of fiber-cleaning tests were conducted during the latter part of 1927. Although no mature abacá stalks were available at that time, and the laborers who did the cleaning were entirely inexperienced in work of this character, fiber of very promising quality was obtained. Samples of this fiber that were subsequently tested at the National Bureau of Standards in Washington had an average breaking strength equal to that of good grades of Philippine abacá fiber.

With a fairly large supply of propagating material available, two 25-acre field plantings were made during 1928 in locations having somewhat different soil conditions. Five different varieties of abacá and four different planting systems were used. The luxuriant growth of abacá in this region indicated that a wider spacing than the 10 by 10 feet, which is the usual Davao system, would be necessary. In making these plantings, the practices followed were essentially the same as those used for bananas. This procedure seemed to be advisable because all the local labor is familiar with the methods used in planting and cultivating bananas. The abacá in these fields made an excellent growth, and the plants when 1 year old compared favorably in size and quality with abacá plants grown under similar conditions in the Philippine Islands.

By 1929, so well had these early plantings succeeded that consideration was being given by the United Fruit Co. to further expansion, and to the need for information on which to base commercial development. One of the small Hagotan fiber-cleaning machines was obtained from the Philippine Islands, and in August 1929 about 1,000 pounds of Panama abacá fiber were shipped to Boston, Mass., for manufacturing tests. The tensile strength of the rope manufactured from this fiber was slightly higher than common Manila rope. A few months later a number of abacá stalks were shipped from Panama to Paterson, N. J., for cleaning tests with a sisal-fiber-cleaning machine. It was demonstrated that abacá could be cleaned with this machine, but the fiber obtained was not of satisfactory quality.

During the early part of 1930 estimates covering the cost of establishing and developing a 1,000-acre abacá planting in Panama were

prepared. At that time the industrial depression was well under way, the future of the world fiber markets was uncertain, and the outlook was not sufficiently favorable to justify further expansion of the abacá plantings. As there was no improvement in these conditions, all the work with abacá at Almirante, except an occasional cleaning of the old fields, was discontinued for a period of nearly 6 years.

THE INTERIM PERIOD

The prospects for any immediate resumption of the work with abacá in Panama were far from bright at this time, but an effort could still be made to maintain a continued interest in the project. In June 1931 the United Fruit Co. extended an invitation to the Cordage Institute and the United States Department of Agriculture to send a commission to Panama for the purpose of inspecting and reporting on the abacá situation at Almirante. This inspection was made during July, and in a subsequent communication from the manufacturers to the United Fruit Co. the following statement was made:

The manufacturers are now convinced that abacá will grow in Panama and are very much impressed by the luxuriant growth of the plants and the quality of the fiber. How it should be cleaned, the cost of necessary machinery and equipment, what markets are available, the probable price obtainable, the competition it must meet, and other similar questions are all for round-table conference. The committee are whole-heartedly interested in this experiment and are prepared to cooperate with the United Fruit Co. to the fullest extent.

Although this inspection did not result in any immediate development of abacá production in Panama, it served to stimulate an interest in this project, and it furnished the cordage manufacturing industry first-hand information that proved subsequently to be of great value.

Several different factors contributed during the early part of 1936 to a revival of interest in the Panama abacá project. The improvement of general industrial conditions had resulted in a corresponding improvement in the fiber market. In the Philippines, the Japanese were steadily increasing their control of the abacá industry, and the advisability of establishing in the Western Hemisphere a secondary source of supply of this fiber was becoming increasingly evident. The possibility of using Central American abacá fiber as a paper material was receiving the attention of United States paper manufacturers.

In April 1936 representatives of the United Fruit Co., the Cordage Institute, and the United States Department of Agriculture, conferred in Washington on means by which abacá production in Panama might be established on a commercial basis. Tentative plans were prepared for a cooperative project under which the United Fruit Co. would agree to plant and maintain 1,000 acres of abacá and install necessary machinery and equipment, and the cordage manufacturers, acting

through the Cordage Institute, would agree to buy all fiber produced during a period of years at a price that would make it possible to write off the investment. It was estimated that this project would cost about \$250,000. The work of assembling additional data both on the plantation and in the cordage industry was started; and, at a meeting of the Cordage Institute held in September, it was voted to cooperate in this project. Several conferences were subsequently held in New York and Boston, and in November the United Fruit Co. decided to proceed with this work without any contract from the manufacturers other than a guarantee that the product of 1,000 acres would be purchased at the prevailing market price for comparable fibers.

PROGRESS DURING THE PREWAR PERIOD, 1937 TO 1941

Early in 1937 two representatives of the United Fruit Co. visited the Philippine Islands to study the conditions under which abacá fiber was being produced in that country, especially to obtain detailed information concerning the different methods of cleaning the fiber. It was the opinion of the engineer who made this study that the results obtained with the large fiber-cleaning machines in use at that time on two of the Davao plantations were unsatisfactory, and that it might be possible to build a machine of an entirely different type that would produce a better quality of fiber. The work of designing and constructing this so-called water-knife machine was started, and a field planting of 1,019 acres of abacá was made at Almirante during the second half of 1937. The two 25-acre plantings that had been made in 1928 furnished a supply of propagating material adequate for this new 1,000-acre planting.

With this relatively large area of abacá, it was then possible to conduct certain lines of experimental work relating to the production of fiber under commercial conditions. As approximately 96 percent in weight of the abacá stalk is waste material, the transportation of the stalks from the fields to a centrally located cleaning plant is a serious problem. In the production of bananas, mules are used for transporting the bunches of fruit from the fields to the spur-railway line; and it was found that abacá stalks cut into 6-foot lengths, which are known as junks, could be moved in the same manner and at a moderate cost. The acreage production of bananas has been materially increased by the use of a system of pruning, which is the removal from each "mat" or hill of bananas of all but a limited number of stalks. Experimental work in pruning abacá indicated that considerably increased yields could also be obtained with this crop. While these field experiments were under way, several shipments of abacá stalks were made from Almirante to Boston where experimental work was being conducted in the cleaning and processing of the fiber.

In 1939 a second field planting of 1,000 acres was made, and the water-knife machine was completed and installed on the plantation at Almirante. Twenty bales of fiber that had been cleaned with this machine were shipped to the United States for manufacturing tests. This fiber was found to be of fairly acceptable quality, but continued operation of the machine under plantation conditions demonstrated the fact that it did not have sufficient cleaning capacity for profitable use in the commercial production of fiber. Plans were prepared for remodeling this machine, and the construction of a new machine was started in the United States.

In the meantime a large acreage of abacá had matured at Almirante and no means of cleaning the fiber were available. It was decided, therefore, to construct and operate at Almirante about 20 of the small Hagotan machines that are used on the Davao abacá plantations in the Philippine Islands. It was not expected that the use of these small machines would be the final solution of the fiber-cleaning problem in Panama, but it would at least furnish a means of salvaging a portion of the abacá stalks that were rotting in the fields. These machines were installed at Almirante early in 1940, were operated for nearly a year, and several fairly large shipments of fiber were made to the United States. This fiber was of different grades and qualities but, in general, was of a quality entirely acceptable to the cordage manufacturers. It was determined, however, that because of high labor costs the cleaning of abacá fiber with these small machines would not be practicable in Panama. From an educational point of view this cleaning project was definitely worth while, as it served to demonstrate to all the larger cordage manufacturers in the United States that when cleaned by the same method there is no essential difference between abacá fiber produced in the American Tropics and that obtained from the Philippine Islands.

The first 11 months of 1941 was another depression period in the Panama abacá project. Two thousand acres of abacá had matured and were ready for harvesting, and no satisfactory method of cleaning had been developed. It had been found that the use of the small machines for the commercial production of fiber was not practicable and the use of these machines had been discontinued. The new water-knife machine had been installed and operated at Almirante, but this machine was still in the experimental stage of development. In the meantime war clouds were gathering and stock piles of Philippine abacá fiber were being accumulated in the United States. It was evident that there was urgent need for positive action with respect to the development of abacá production in the Western Hemisphere, but with conditions in the Orient still in the "pending" stage neither the Government nor commercial interests were prepared to take this action.

THE WAR PERIOD

The status of the Panama abacá project was immediately and completely changed by the happenings at Pearl Harbor on December 7, 1941. The supplies of abacá available in the United States at that time were entirely inadequate to meet the probable requirements for this fiber, and the prospective occupation of the Philippine Islands by the Japanese meant that our main source of supply of abacá would be cut off for an indefinite period. Under these circumstances the need for developing the production of this fiber in Tropical America could not longer be questioned.

Two days after Pearl Harbor the Interbureau Coordinating Committee on Special Fiber Crops, of the United States Department of Agriculture, met in conference for consideration of different aspects of the Panama abacá situation. One of the members of this committee was authorized to discuss this matter informally with representatives of the Office of Production Management, the Cordage Institute, and the United Fruit Co. for the purpose of determining what action might be taken. In December 12 a conference was held by representatives of the Reconstruction Finance Corporation, the Defense Supplies Corporation, the Department of Agriculture, the United Fruit Co., and the Cordage Institute. It was proposed at this conference that the United Fruit Co. should immediately purchase a Corona fiber-cleaning machine that was available in Costa Rica and move this machine to the plantation at Almirante, that plans should be prepared for the planting by the United Fruit Co. of approximately 10,000 acres of abacá in Panama and 10,000 acres in Costa Rica, and that with the approval of the Office of Production Management this project should be financed by the Reconstruction Finance Corporation. The necessary contracts covering this work were subsequently prepared, but without waiting for the approval of these contracts, instructions were cabled to Almirante, the machine was purchased and moved, and planting operations were started.

The casual observer who may have occasion to watch the discharge of a cargo of Central American abacá on a dock in New York, probably has but little conception of the difficulties that had to be overcome before this fiber could be produced. The conditions under which the abacá plantations were established in Central America have been well described in an article published in *Cord Age* magazine, September 1944, from which the following is quoted:

When the plantations were started shortly after Pearl Harbor, there was lack of knowledge in the cultivation and processing of the fiber. The only abacá grown in this hemisphere was that produced by the experimental plantation operated by the United Fruit Co. in Panama, with root stock provided by a far-sighted member of the United States Department of Agriculture, who had brought the stock from the Philippines.

There was scarcity of labor in Central America due to other competing war projects. There was scarcity of machinery, materials, and supplies which were required in substantial quantities for these large-scale enterprises. The demands upon the limited quantities available in the United States were practically unlimited.

There was scarcity of shipping and submarines were taking a large toll. There was congestion on our railroads and docks holding up deliveries. These difficulties and the fact that it takes approximately 2 years to grow abacá from the time of planting made the problems of producing this essential fiber before our stockpile ran out almost insuperable.

The Central American countries were scraped clean for materials and labor. Unable to receive machinery and equipment from the United States, there was much ingenious improvisation. Machetes were made out of steel rails, fan belts were made out of rope, second-hand irrigation pipe was used to drill wells for water supply.

In establishing these plantations it was necessary to make elaborate soil surveys to select the proper sites. Hundreds of miles of land were surveyed by engineers to take topography necessary for drainage systems and to lay out plantations and railroads. It was necessary to fell and underbrush the dense jungle vegetation.

Approximately 7,000,000 heads of seed (rhizomes), approximately 27,000 tons, had to be dug from the experimental plantation in Panama, transported to ports, shipped to the various countries where plantations were established, and hauled from ports of these countries inland to the plantations. This had to be done with as little delay as possible in order to preserve the seed, a difficult problem with scarcity and irregularity of shipping and inadequate inland transportation.

Because of the rapid growth of vegetation in the tropics, much labor had to be used to clear competing vegetation during the early growth of the plants. Hundreds of miles of drainage had to be dug and cleaned to carry off excess water, destructive to abacá roots.

Roads and bridges had to be constructed through the jungle growth to provide passage for mules carrying seed to the plantations and later the stalks to the railroads.

Elaborate railway and tram systems were established to transport the stalks to the factories and the fiber from factories to the railways.

Large factories to extract the fiber from the stalks had to be constructed and machinery designed and manufactured to carry out large-scale production, consisting of decorticators, crushers, driers, balers, and auxiliary machinery.

By April 30, 1945, approximately 29,000 acres of abacá had been planted and were under cultivation in the four countries of Panama, Costa Rica, Guatemala, and Honduras. A large part of this acreage was in production and as abacá is a perennial, production was expected to continue for some 10 or 12 years without replanting. Five large fiber-cleaning plants had been installed by 1945 and were in operation. During three war years, more than 20,000,000 pounds of abacá fiber had been produced and practically all of it had been shipped to the United States and manufactured into rope. In the meantime the pre-war stocks of Philippine abacá had been largely, or entirely, exhausted, and the Nation's one source of supply of this fiber was Central America.



1. FIELD OF ABACÁ IN ALBAY PROVINCE, ISLAND OF LUZON.

Note the jungle surroundings. Although grown and processed under primitive conditions, large quantities of abacá fiber of excellent quality have been produced in southern Luzon. (Photograph courtesy Philippine Bureau of Agriculture.)



2. FIELD OF ABACÁ IN DAVAO PROVINCE, ISLAND OF MINDANAO

The Davao abacá plantations, with efficient management and modern methods of cultivation, produced in the prewar period large yields of fiber of superior quality. This field on the O. V. Wood plantation furnished many of the plants that were shipped to Panama (Photograph courtesy Philippine Bureau of Science.)



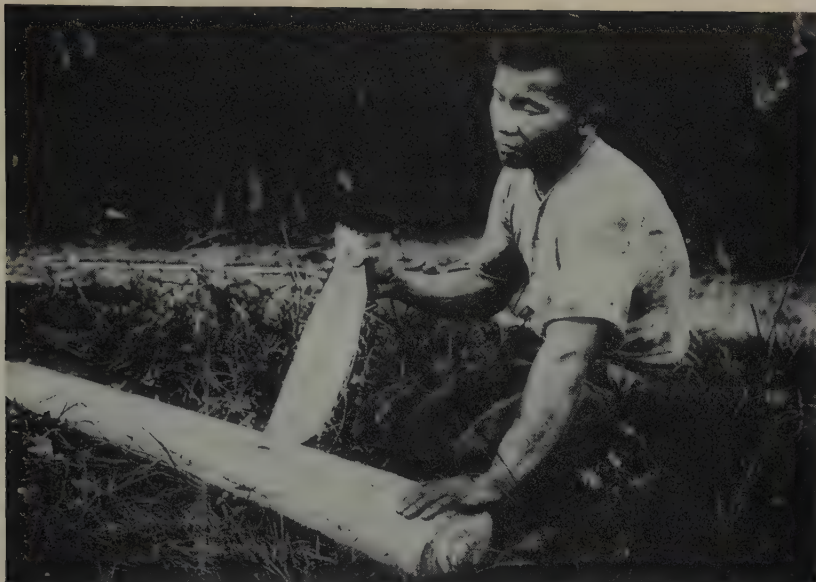
1. CLEARING LAND FOR AN ABACÁ PLANTING IN DAVAO PROVINCE.

One of the many difficult problems of the planters is the removal of the large trees on land that is to be planted to abacá. Note the method of felling above the buttresses of this tree.



2. A RECENTLY CLEARED AND PLANTED ABACÁ FIELD IN DAVAO PROVINCE.

This field has been cleared of virgin forest, the brush and trash have been burned, and the abacá rhizomes have been planted.



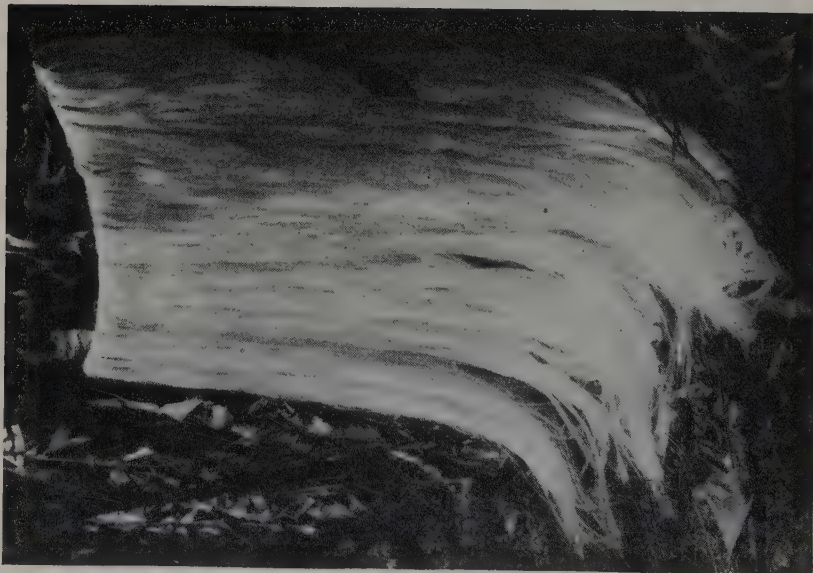
1. "TUXYING" ABACÁ.

The first operation in cleaning abacá fiber by the hand-stripping process is the removal of the fiber-bearing outer layer of the overlapping sheaths of the stalk. These fibrous ribbons are known as tuxies. (Photograph courtesy Philippine Bureau of Agriculture.)



2. STRIPPING ABACÁ FIBER.

The native method of cleaning abacá fiber in the Philippines is by pulling the tuxies under a knife (usually serrated) that is pressed down against a block of wood by means of a spring pole. (Photograph courtesy Philippine Bureau of Science.)



1. DRYING ABACÁ FIBER IN DAVAO PROVINCE.

The usual method of drying abacá fiber in the Philippines is by hanging the freshly cleaned fiber over bamboo poles. Under favorable conditions the fiber will dry in a few hours. (Photograph by the author.)



2. TRANSPORTING ABACÁ FIBER IN ALBAY PROVINCE.

Abacá fiber produced in the foothill regions is packed in "bultos" of about 100 pounds, and is transported for long distances over rough trails by native cargadores. (Photograph by the author.)



1. TRANSPORTING ABACÁ FIBER IN SOUTHERN LUZON.

In the coastal regions, or in places where there are roads, abacá fiber may be taken from the farms to the nearest market town in carabao carts. (Photograph courtesy Philippine Bureau of Science.)



2. TRANSPORTING ABACÁ FIBER IN DAVAO PROVINCE.

On the larger plantations in Davao Province, the bultos of abacá fiber are usually moved from the plantations to the markets with motor trucks. (Photograph by the author.)



1. GRADING ABACÁ FIBER IN DAVAO PROVINCE.

Abacá fiber delivered by the producers at the presses and warehouses is sorted into different grades before being baled. (Photograph by Ralph McFie.)



2. INSPECTING ABACÁ FIBER.

All abacá fiber exported from the Philippine Islands is graded according to established official standards, and is examined by government inspectors before exportation. (Photograph courtesy Philippine Bureau of Agriculture.)



1. FIELD OF ABACÁ IN CHANGUINOLA DISTRICT, PANAMA.

These plants, which are about 9 months old, are a part of a 1,000-acre planting of abacá made in 1937. (Photograph courtesy United Fruit Company.)



2. FIELD OF ABACÁ IN CHANGUINOLA DISTRICT, PANAMA.

These plants, which are about 18 months old, are in the same field shown in the previous picture. (Photograph courtesy United Fruit Company.)



1. MAT OF BUNGULANON ABACÁ BEFORE PRUNING.
A system of pruning, which consists in removing from each mat all but a limited number of stalks and which has largely increased the yield of bananas, is now being used with abacá. (Photograph courtesy United Fruit Company.)

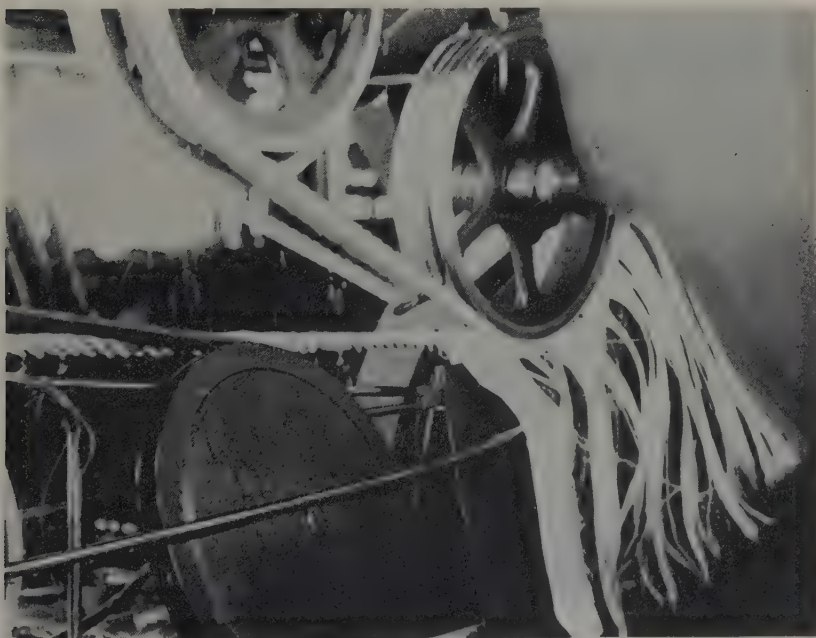


2. MAT OF BUNGULANON ABACÁ AFTER PRUNING.
This is the same mat of abacá shown in the previous picture, after many of the stalks have been removed. (Photograph courtesy United Fruit Company.)



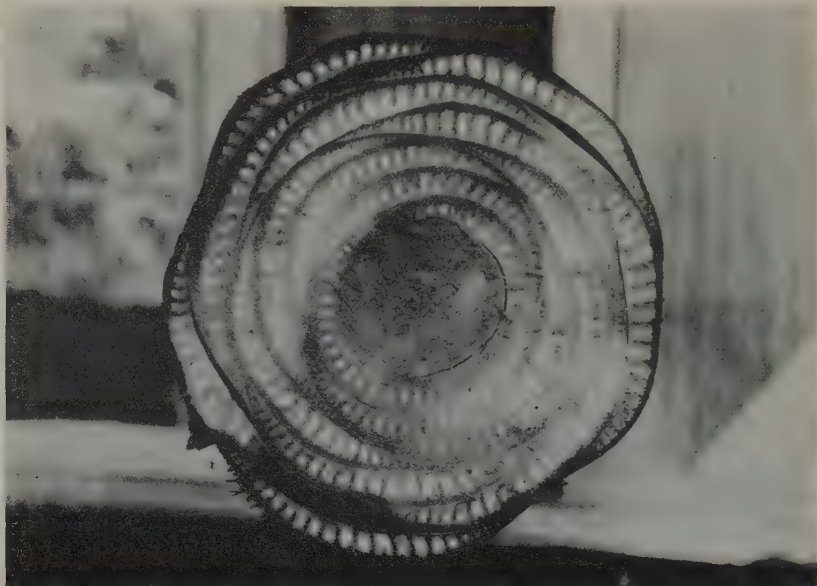
1. INTERIOR OF A FIBER-PROCESSING FACTORY, PANAMA.

The abacá stalks are first crushed into a "blanket," which then passes through the decorticating machine. The cleaned fiber passes through squeeze rolls, is then artificially dried, and finally is baled. (Photograph courtesy United Fruit Company.)



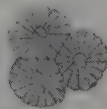
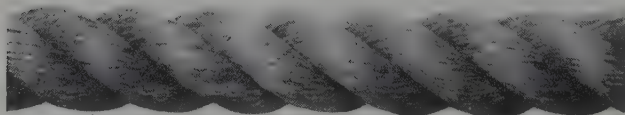
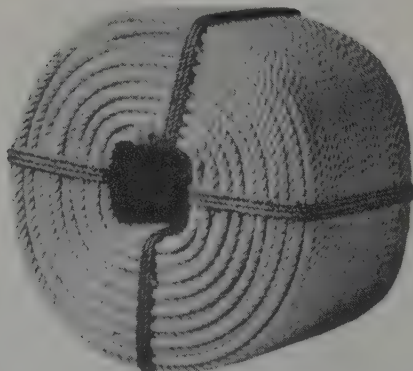
2. ABACÁ DECORTICATING MACHINE.

The crushed abacá stalks as they pass through the decorticating machine are carried over curved metal plates, and the fiber is cleaned by a scraping process which removes all pulp and waste material. (Photograph courtesy United Fruit Company.)



1. CROSS SECTION OF ABACÁ STALK.

The abacá stalk, except for the central core, is made up of a series of overlapping sheaths, each one of which was originally the stem of a leaf. The fiber is obtained mainly from the outer portion of these sheaths. (Photograph courtesy United Fruit Company.)



2. COIL, SECTION, AND CROSS SECTION OF MANILA ROPE.

This three-strand, one-half inch diameter Manila rope, which is made from Philippine abacá fiber of high quality, has ample strength and durability for all general purposes. (Photograph courtesy Plymouth Cordage Company.)

GROWING RUBBER IN CALIFORNIA ¹

By E. L. PERRY

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U. S. Forest Service, Los Angeles, Calif.*

[With 4 plates]

Back in 1852 a physician and amateur botanist named Bigelow, who was attached to the Mexican Boundary Survey, collected a plant specimen new to him in the Big Bend section of Texas and sent it to Prof. Asa Gray of Harvard for identification. It was a low shrub, something like sagebrush, with grayish-green foliage and small, yellow, composite flowers. It was also new to Gray, so he named it *Parthenium argentatum* and described it.

But the plant was not new to the natives of that section and north-central Mexico, where it grew freely. They called it guayule (y-oó-leh) and had long since discovered that its bark contained a gum which when extracted could be molded into a ball that bounced. It is said that whole communities engaged in mass chewing of the bark for the purpose of making play balls.

The gum was rubber, and rubber was beginning to find ever greater demand in the United States. When the Centennial Exposition opened at Philadelphia in 1876 the Mexican State of Durango—in the best chamber of commerce tradition—sent a guayule exhibit in an effort to interest Yankee capital, but the idea failed to take hold. In 1888, a New Jersey rubber firm, apparently under a misapprehension regarding the true nature of the guayule plant, sent an emissary to Mexico to procure a quantity of “guayule bark.” The traveler found guayule to be a 2-foot-high shrub, but he was out of touch with his firm so he took a chance and shipped home 100,000 pounds of the entire shrub. His bosses were thoroughly disgusted, but they laboriously peeled the stuff, boiled the bark, and extracted what rubber could be recovered by that means. The only bright spot in the whole business was the fact that the rubber was found to be of excellent quality.

¹ Reprinted by permission, with additional illustrations, from the *Journal of Forestry*, vol. 42, No. 5, May 1944.

EXPERIMENTS IN EXTRACTION

As a matter of fact, it was the extraction difficulty that was holding back development of a guayule rubber industry. Unlike the hevea tree, where the rubber-bearing latex is contained in perpendicular tubes which flow when severed, guayule latex is stored in unconnected small cells so that tapping the plant releases an inconsequential amount of the fluid.

The Indians chewed the bark, thus freeing the rubber and agglomerating it in the mouth, but it was only after years of experimentation with chemical extraction processes that anyone thought of duplicating the chewing process on a large scale. Wm. A. Lawrence, a chemist who had been employed by some American capitalists to study the problem, and who also spent a couple of years searching for a chemical solution, finally hit upon the mastication process. The common "pebble" or "ball" mill of the mining industry was found to be virtually made to order for guayule milling, and by 1904 the guayule rubber business was firmly established in Mexico.

A mill was also built at Marathon, Tex., about 1909, and operated sporadically over a period of several years. It was dismantled in the twenties because the accessible shrub supply had run out, but it is interesting to note the truth of the old copybook maxim, "circumstances alter cases"—the Emergency Rubber Project has just completed harvesting some 2,400 tons of shrub there, regardless of inaccessibility. Since the quantity did not justify building a mill there, the shrub was shipped to Salinas, Calif., and processed in the project's plant. It added about one-half million pounds of badly needed natural rubber to the nation's dwindling stock pile.

EXPERIMENTS IN CULTIVATION

The principal guayule operator in Mexico early began to wonder about the fate of the industry once the wild-shrub supply should become exhausted. The plant is native only to the high, arid plateau country from the Pecos River down through north-central Mexico, where the average annual rainfall varies from perhaps 8 or 9 to 12 or 15 inches, and where plant growth is slow and reproduction scant and uncertain. Guayule may live for 40 or 50 years, and it is said that the average age of shrub harvested is about 15 years. It is a poor competitor, hence grows only on sites not pre-empted by other plants, such as eroded hillsides and ridges. Thus the plant occurs in rather sparse stands in scattered patches, and on the open range is not potentially a crop such as to intrigue a prudent husbandman. Various attempts to improve reproduction by seeding, and even by rough tillage of the soil, proved fruitless.

So the company decided to try domesticating the plant. It employed a young botanist, Dr. W. B. McCallum, and told him to go ahead.

McCallum started out on the company's property in Mexico. The revolution broke out in 1912, however, and after the contending forces had chased each other across his experimental plots a few times the researcher pulled out in disgust for southern California. He settled first at Valley Center, and here, too, the project has just finished harvesting shrubs planted in 1913-1914. He shortly decided to grow the crop under irrigation, however, and moved to southern Arizona. He finally concluded that this was a mistake, but during the several years he was there McCallum set out experimental plots from northern California through southern Arizona, New Mexico, and southwestern Texas. On the basis of these plots he finally decided that the Salinas Valley of California was the place and in 1925 moved his headquarters there. In 1931 a mill was built and during the next 10 years some 4,500 acres of guayule were grown and milled.

During that period of nearly 30 years, Dr. McCallum had considerably improved the productivity of guayule. On its native range the plant exists in almost countless varieties or strains, some very good and others exceedingly poor. By a process of selection he weeded several hundred strains down to a dozen or less of good producers. Of these, four form the mainstay of production, possessing among them certain other attributes required to meet varying conditions of site.

He also worked out methods for propagating the plant and growing it, and other employees of the company designed machines for seeding the nurseries, setting out plants, collecting seed, and harvesting shrub. The so-called Stevenson plan of controlled exports from the Orient had forced the price of rubber up to a high in 1925 of \$1.23 per pound, which made of guayule a potential gold mine.

With the abandonment of the cartel and the coming of the depression rubber prices sank to a disastrous low of 3 cents in 1933, which effectively ranked guayule with the other bursted bubbles of history. Some guayule fields were burned or plowed up by the contracting farmers, but those who held on came out fairly well since the price rose again as the market regained equilibrium. The New York price of plantation rubber was 22½ cents at the time of Pearl Harbor.

THE GOVERNMENT STEPS IN

With true scientific detachment Dr. McCallum kept plugging along through thick and thin. When the war broke out and the Government began casting about for every possible source of rubber, he had in storage 23,000 pounds of seed from his prize strains.

It was this seed that the Government was principally after when the deal was made to take over the Intercontinental properties. The deal had been in the making even before the outbreak of the war. Representative John Z. Anderson of California had introduced a bill on June 12, 1941, for that purpose, but nothing came of it. When war was declared he reintroduced it and on March 5, 1942, it became law. It provided for purchase of the Intercontinental properties and patents in this country and the growing of 75,000 acres of guayule. The company received \$1,721,235.

With the signing of the Guayule Act there was launched an epic of construction activity that I am sure has not been topped during the history of this country's war effort. The time was already at hand when the guayule seed must be sown and there were no nurseries in which to sow it.

Under the dynamic hand of Maj. Evan W. Kelley, sent from his post as regional forester at Missoula, Mont., to head up the job, and the organizational genius of Paul H. Roberts, erstwhile director of the Midwestern Shelterbelt Project, that situation was soon remedied. In the face of almost incredible difficulties in respect to procuring material and help, 600 acres of nursery land were leased, leveled, equipped with overhead irrigation, buildings, and windbreaks, and seeded. A thousand-man labor camp was constructed and equipped, and 905 acres of fields were planted with stock ready for transplanting in a small nursery operated by the company. And over all was the necessity for recruiting, often sight unseen, a corps of men who knew nothing about guayule but could nevertheless be trusted to go ahead largely on their own without disastrous consequences.

The author can record all these heroic achievements with perfect modesty; he was not there until they were nearly finished. But the record speaks for itself. The 23,000 pounds of seed got into the ground in time, and in due course, while everyone hung breathless over the beds, emerged as some 300 million healthy plants. Carpenters on the camp job kept one jump ahead of incoming laborers, and the organization—mainly by virtue of the 7-times-a-week "breakfast conference"—managed to correlate its myriad activities into some semblance of homogeneity. Salinas is a small town, so personnel lodged wherever it was lucky enough to find room, and the project's offices were at one time scattered out in 14 places, including cottages on the edge of town.

HANDLING THE NURSERY CROP

When the guayule plants came up in the nursery beds, weeds came too, and since the young rubber plants start slowly, there was a giant weeding job on hand. Some 3,000 people were engaged in that back-

breaking activity at the height of the campaign, half of them women and girls recruited from the town and surrounding country. Weeds are killed in the nurseries with oil sprays now, but there was no time to experiment then.

All this frenzied activity subsided somewhat once the nursery crop got established, but not for long. The 700 acres of guayule fields taken over from the company, plus that spring's plantings and even the nursery beds, began to ripen seed. The company had developed a mechanical picker, but it was wasteful of seed so again a large labor force was recruited and put in the fields with brushes and trays collecting seed. When it became obvious that a larger quantity of seed than had been expected was going to be harvested, Congress raised the 75,000-acre limitation on the planting program to 500,000 acres, and once again the project went into a high-speed nursery-building program.

With the hope that a crop of seedlings could be grown during the winter, two groups of nurseries, each comparable in size to the Salinas lay-out, were constructed in southern California. In order to have a completely realistic unit of measurement in connection with nurseries a standard "bed" was established, being 4 feet wide and 400 feet long. Thus, the Salinas nurseries contained 12,000 beds, while those at Indio and Oceanside contained 9,900 and 11,100 respectively. Later, a 6,000-bed nursery was built in the San Joaquin Valley, one of 3,000 beds near Las Cruces, N. Mex., and two of 1,500 beds each in the Salt River Valley of Arizona and the lower Rio Grande Valley in Texas. We had a total at one time of 45,100 beds, sufficient to produce stock for an annual planting program of about 200,000 acres, assuming that the southern California nurseries could be double-cropped. For the benefit of those who may have difficulty in thinking in terms of "beds," these nurseries occupied a net area of about 2,000 acres, all equipped with overhead irrigation.

REVISIONS IN PROGRAM

It will be noted that a good deal of this latter discussion has been in the past tense. Actually, some of this acreage was never seeded, some of it has been dismantled, and doubtless more of it will be. In the spring of 1943 the rubber director advised the Secretary of Agriculture that in his opinion the rubber situation no longer justified diversion of highly productive farm land to guayule, and later, by arrangement between them, the program was curtailed to a total field acreage of about 32,000, that being the amount of land then planted or on which the Government had commitments which could not be released.

There were a number of reasons for this action. Anxious to produce rubber as quickly as possible, the project had settled on a policy of leasing only good land, mostly irrigated, and rental values of such land had soared under the impact of war demands for food. Since the project plan called for 10-year leases, it wanted to get the land at rates not too greatly reflecting the war boom, and getting into agreement with landowners on that basis was difficult. Dissatisfaction resulted, which found expression in questioning whether guayule was of greater value in the war effort than the food crops which could be grown on the land.

In the meantime, the synthetic rubber program had developed better than probably anyone had dared hope for, and the winds of the Pacific conflict had begun to veer around in our favor, holding out hope that the Japanese might be driven out of the rubber plantations earlier than previously expected. Altogether, the rubber director felt that the guayule program should be suspended at the existing level, but held in a "stand-by" position in case anything should happen to require resumption later on, and the Secretary naturally was constrained to accept his judgment in the matter.

Later, the rubber director requested that the program be resumed on a modified scale to produce 20,000 long tons of rubber per year, but by that time Congress had gotten out of the mood. The House Appropriations Committee refused to approve the expansion, taking the stand that the added rubber production could not be realized before the probable end of the war.

So at this writing the Emergency Rubber Project has simmered down to the growing out and eventual processing of some 32,000 acres of guayule, growing in five districts in California—the Salinas Valley, upper San Joaquin Valley, lower San Joaquin Valley, Sacramento Valley, and southern California. In addition about 120 indicator plots and other experimental plantations are scattered from northern California through the Southwest to the Gulf of Mexico.

GUAYULE AS A RUBBER PRODUCER

Now a word about guayule as a rubber producer. As noted previously guayule rubber has been on the market for 40 years or so in competition with hevea rubber, though it normally sells for about 20 percent less. The reason for this is that the resins in the plant become mixed with the rubber in the milling process, the resin content running from 16 percent to 20 percent or higher, depending on the age and other characteristics of the shrub. While means of deresinating the rubber are well known, the producers have never had any incentive to do so; the product has found a ready market for purposes where the

resin is not disadvantageous, and to deresinate it would merely reduce the volume so as to counterbalance the increase in price.

Getting the best returns from guayule under cultivation is subject to a considerable array of variables. Harvesting and milling costs depend largely on the amount of shrub that must be processed to obtain a pound of rubber, and big shrub with high rubber content is an elusive combination. It is when growth slackens or is suspended because of lack of moisture, cold weather, or some similar circumstance that rubber percentage begins to rise. The theory is that the carbon fixed by the leaves is largely used up in growth and seed production when environmental conditions are favorable for those functions, but when conditions are unfavorable and growth and flowering slow down or stop, the plant, continuing to assimilate carbon, seeks to store it in some appropriate form. The compound chosen happens to be the pure hydrocarbon, rubber.

Thus, if you attempt to force the plant too hard, as by irrigation, you get a magnificent shrub, but one containing a low percentage of rubber. The reason Dr. McCallum chose the Salinas Valley for guayule growing is that there is an invariable alternation of wet winter and spring with a long, dry summer and fall, thus automatically affording the conditions necessary for both plant growth and rubber deposition. On unirrigated land there, the optimum rotation, from an economic standpoint, appears to be about 5 years, and at that age a good field may produce up to 1,800 pounds of rubber per acre.

Under irrigation, where unseasonable rainfall does not interfere, this rotation may be shortened by properly manipulating the irrigation water. Under the stress of the original program it was planned to grow it only 2 years under irrigation, spacing the plants closely (28 inches by 20 inches) to obtain optimum volume on the land. This rotation is not considered economically sound, though actually there has never been sufficient information collected on the behavior of the plant under irrigation to justify definite pronouncements on the subject.

RESEARCH PROGRAM

That subject is being studied now, and incidentally one of the bright spots of the program is the fact that a magnificent job of research is being done on it. While the operational phases of the project are under the direction of Paul H. Roberts, who succeeded Major Kelley when Kelley returned to his post at Missoula in 1943, the Bureau of Plant Industry, Soils, and Agricultural Engineering has a corps of scientists under the able leadership of Dr. A. C. Hildreth following almost every imaginable line of investigation in connection with the plant itself; and the Bureau of Agricultural and Industrial Chemistry

has a large pilot plant and laboratory seeking better methods of rubber extraction, under the direction of F. Macdonald.

Dr. W. G. McGinnies of the Forest Service heads a division which has made an almost foot-by-foot survey of the probable range of the plant, determining and classifying the areas adapted to its culture, and studying the behavior of indicator plots. T. P. Cassidy of the Bureau of Entomology and Plant Quarantine has made an intensive study of the plant's insect relationships. Other members of the organization have invented or improved cultural machinery, including a new and simple seed-collecting machine which enabled the project to harvest more than one million pounds, rough weight, last season.

Past research in plant improvement has been confined almost entirely to selection among varieties and strains, but the geneticists are now tackling actual breeding up of the plant. It has certain peculiarities that promise to challenge their ingenuity, but there is every reason to suppose that the plant is susceptible of considerable improvement. It is very choosy about its site requirements; it demands a friable, well-drained soil and contracts various fungous diseases if conditions are unfavorable. It also does not like temperatures much below freezing. These characteristics greatly restrict its range, of course, and the scientists are investigating the possibility of increasing its tolerance in those respects.

RUBBER-EXTRACTION PROCESS

The rubber-extraction process is virtually the same one the industry started out with 40 years ago, and while it recovers a satisfactory proportion of the rubber from the shrub, it is cumbersome and expensive and also mixes with the rubber foreign substances that the processors would very willingly dispense with. Briefly, the milling process is about as follows.

After being dug or pulled out of the ground, the shrub is cured in the field 2 or 3 days, then baled and stored till needed. In the mill, it is chopped up and the chips dried down to about 15 percent moisture content. It is then crushed, mixed with water, and fed into a series of pebble mills. These are revolving tubes lined with rough silica bricks and about one-third filled with flint pebbles. The pebbles cascading down the wall thoroughly macerate the material in the slurry, freeing the rubber from the fiber. The slurry is then discharged into a vat, where the water-logged wood sinks and the rubber floats and is skimmed off. After certain other cleansing operations the rubber is dried and pressed into 100-pound cakes.

The mill at Salinas, which is capable of handling about 30 tons of shrub in 24 hours, cost some \$207,000 to build in 1931. There is not

much doubt that the chemists and engineers will considerably improve this process and they may revolutionize it.

Nothing has been done about possible byproducts so far, though there are some interesting possibilities. A number of essential oils have been extracted from the plant experimentally and it is rich in resins. The bagasse, or woody pulp which remains after extraction, is sometimes used as fuel in the mills, but it may have higher uses than that. It is too finely ground in the pebble mills to be much good for paper, but a very good-looking hard board has been made experimentally by mixing the resinous leaves of the plant with it and subjecting it to heat and pressure. No data are so far available regarding its properties or practicability of manufacture, but certainly there will be a vast amount of the raw materials if guayule is ever grown on a commercial scale.

THE FUTURE OF GUAYULE

And that brings us to the question of the future of guayule, once the Japanese have been ousted from the rubber plantations of the Orient. Can it compete with the East Indies product? And how about our enormous new synthetic industry? Only a grade-A prophet would be qualified to speak with any certainty on that subject. There are too many unknown quantities. But here are a few considerations to speculate on.

1. No one knows yet the cost of producing guayule rubber on a commercial scale. While the Intercontinental Co. grew a few thousand acres of it over a period of several years, both for its own account and under various forms of contracts with farmers, there is not a sufficient volume of accurate records upon which to base a reliable cost figure. One thing is reasonably certain—it cost more than East Indies rubber did before the war, but balanced against that is the virtual certainty that the researchers will radically improve guayule cultural and processing methods and probably the plant itself. Incidentally, they already have improved the quality of the product, so that the industry has come to prefer guayule rubber turned out by the Salinas mill.

2. It is uncertain what the plantation rubber situation will be after the war. Since the Japanese have no use for the entire normal output of the plantations they may clear off part of them for other purposes, or at least neglect them and let them revert to jungle. Or they may try to destroy them in a "scorched earth" attempt before they leave.

In any event, a rubber-starved world is going to require an enormously abnormal amount of the substance for a while at least, which of course will tend to hold the price up. There does not seem to be much prospect for any very cheap rubber from abroad, for some time at least.

3. The speed with which the synthetic rubber industry has been developed ranks among the major miracles of our war effort, but there are some flies in that ointment, too. The principal one is that no one has so far been able to compound a true synthetic rubber, and the substances which are being used to substitute for the natural product lack some of its virtues. Normally about 72 percent of the rubber used in this country goes into tires, and the synthetics are not as good as natural rubber for that purpose. Mixing the two helps a lot, and even German tires captured today assay a goodly percentage of natural rubber.

On the other hand, synthetic rubber is better for some purpose than the natural product, so there will always doubtless be a market for a certain quantity of it regardless of the availability of crude. Specific cost figures have not yet been released, but its proponents freely predict that it will eventually get onto a competitive basis with plantation crude. Then, too, the chemists are working desperately to improve their product and there is always the chance that they may develop a synthetic equal in all respects to natural rubber. The fact that the Germans have not done so in 30-odd years of experimentation is by no means proof positive of its impossibility. There is a lot of money and human ambition tied up in this huge, if still embryo, industry, and you can wager that a tremendous struggle will be made to avoid having to junk it after the war.

4. When the war is over, one school of thought will be certain that we must never again become dependent upon a rubber supply thousands of miles over the sea. But another will be equally insistent that we must buy rubber from the East in order to sell goods there. Which will be the stronger no one now knows. British thought on the subject seems to foresee a compromise whereunder both ends will be served. We would buy some rubber from the plantations but also maintain sufficient domestic production to provide for a quick expansion to self-sufficiency if necessary.

WHAT PRICE GUAYULE?

So what price guayule? Standing between a 750-million-dollar synthetic colossus on the one hand and a million-ton-per-annum hevea giant on the other, it is apt to be trampled under foot unnoticed. And yet, there is an excellent chance that it may be one of those rare stones capable of killing several economic birds at one fling. There is no doubt about the quality of the product, and in conjunction with our best synthetics it could serve all our rubber needs. We would have a source of rubber, to quote the Baruch report, "which could not be lost to us short of conquest of American territory." We would have

a new, tough, drought-resistant crop for a section of the country which can very handily use just such a new cash crop in normal times. We would have a new industry for the employment of American labor and capital.

Maybe none of those considerations will be strong enough to prevail against the natural urge of a ration-weary nation to cut all speculation and head for the shortest road back to normal stock piles. Whatever else is done, though, it would seem to be the part of common sense at least to continue a strong program of guayule research, and on a sufficient scale to test its possibilities under conditions of commercial production. There is still a vast deal to be learned about guayule, in fact we are only at the threshold of the subject. Rubber is one of our really dangerous national deficiencies and we ought not to overlook any bets where it is concerned.

POSTSCRIPT

A great deal of water has gone over the guayule dam during the relatively brief time since the foregoing was published, in May 1944. Another high peak and another very low valley have been added to the already extremely eccentric chart of the Emergency Rubber Project's history.

Early in 1945 the natural-rubber situation became so acute that a committee from the rubber industry surveyed the guayule fields and recommended the immediate harvest and milling of the entire crop, regardless of its immaturity. Four new mills were to be built by the Government and operated under contract by the Firestone Tire & Rubber Co.

Preliminary work on the new program was well under way when the Japanese war ended. On the theory that natural rubber from the Orient would shortly start flowing to America again, and considering the admittedly uneconomical nature of the proposed expansion, work on it was stopped. For the time being the project reverted to its original plan to continue with an orderly harvesting of the crop, but in the general clean-up of outmoded war projects it was decided to wind up its affairs and clear the remaining 27,000 acres of land for return to the owners.

Thus is spotlighted the national security values of guayule. While it happened that events broke in such a manner as to make it seem desirable to not harvest some 85 percent of the guayule crop, if the war had continued even a little longer there is no doubt at all that the rubber in it would have been worth almost its weight in gold.

Another event of great potential significance to guayule culture was the introduction in Congress of what is known as the Poage bill. In

1944 a House Committee headed by Representative Poage of Texas made a study of the project and guayule growing in general. The result was introduction of legislation designed to promote guayule growing and processing by private enterprise. The bill, which passed the House but at this writing (December 1945) is still pending in the Senate, provides for a support price of 28 cents per pound for domestically produced guayule rubber for a period of 10 years. The benefits are restricted to a total of 400,000 acres during the period, and to 100 acres per grower per year. It also provides for continuing research in connection with guayule and other rubber-bearing plants.

While guayule development seems to be stalemated in this country, for the time being at least, the project gave impetus to its development elsewhere in the Western Hemisphere. The Continental-Mexican Rubber Co., oldest and largest of the wild-guayule operators in Mexico has launched a large guayule-culture program, using initially 50,000,000 plants supplied by the Emergency Rubber Project. A smaller cultural project in Mexico was started by the General Tire & Rubber Co., which built a mill there during the war. Argentina bought 5 tons of guayule seed from this Government, and is negotiating for the purchase of seeding and transplanting equipment.

So our humble desert shrub, after thirty-odd years of rather diffident knocking, seems at last to have gotten its foot into the door of the Western Hemisphere's rubber business. Whether or not it will be able to stay remains to be seen, but at least its chances have been vastly improved by the intensive research to which it has been subjected during the life of the war-born Government project.



1. FIVE-YEAR-OLD GUAYULE SHRUB GROWN UNDER CULTIVATION ON NON-IRRIGATED LAND IN THE SALINAS VALLEY, CALIF.

When harvested, the entire plant is dug about as shown, since rubber occurs in both the aerial parts and roots. This specimen is somewhat larger and more symmetrical than the average field plant.



2. SEEDING A GUAYULE NURSERY.

The seeder drops the seed on top of a finely prepared bed and then flows a ribbon of sand over them to hold them in place. Guayule plants have trouble emerging if covered with soil. The beds are 4 feet wide and are served by overhead lines spaced 10 beds apart.



1. A 2-YEAR-OLD IRRIGATED GUAYULE FIELD IN THE SALINAS VALLEY OF CALIFORNIA.

[] Note the profuse blossoming, a characteristic of the plant when supplied with abundant water.



2. CULTIVATING A YOUNG GUAYULE FIELD IN KERN COUNTY, CALIF.
The plants are in their first growing season.



1. GUAYULE GROWING WILD IN THE SEMIDESERT PLATEAU COUNTRY OF NORTH-CENTRAL MEXICO, AND THE BIG BEND SECTION OF TEXAS.

A number of rubber mills have operated in this territory for the past 40 years.



2. USING AN OIL SPRAY TO KILL WEEDS IN A CALIFORNIA GUAYULE FIELD.

Diesel oil is emulsified with water and applied at high pressure. The spray kills or injures the weeds, but does not damage the guayule.



1. DR. W. B. MCCALLUM, WHO HAS CARRIED ON A ONE-MAN GUAYULE RESEARCH PROGRAM SINCE 1912. He started with several hundred strains of wild guayule, boiled them down to a handful of the best and most consistent producers.



2. GUAYULE RUBBER AS IT COMES FROM THE MILL. It is pressed into 100-pound slabs for shipment to manufacturers. The rubber contains more resins than plantation crude, but otherwise is similar.

THINKING ABOUT RACE¹

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Recently the subject of race has been lifted from comparative obscurity to the headlines. Nazi racists have asserted the fabulous superiority of one race, while the Japanese have claimed pre-eminence for their quite different physical type. On the other hand, people appalled by Nazi misuse of the idea of race have made nearly as absurd claims about the nonexistence of varieties of *Homo sapiens*. For example, a recent paper started by claiming that there are no differences of functional importance between living races, and proceeded in the same paragraph to proclaim the value of dark pigmentation to people in the Tropics.

It is extremely difficult to try to give an unbiased presentation when emotions are involved. Therefore in this paper I have tried to present ways of thinking about race rather than any particular classification. I hope that the methods outlined will aid the reader in evaluating any racial system and will help to clarify ideas concerning race.

In the first place, as has been repeatedly stated, races are groups which are distinguished on the basis of inherited anatomical characters. Race has nothing to do with language, religion, nationality, or social habits. Race is an expression of nature (inheritance), not nurture (learning). Tozzer (1931)² has given an excellent account, well worth the attention of anyone wanting more information on this fundamental point. Psychological differences between races are probably nonexistent, according to Klineberg (1935) who has made an exhaustive study of this subject.

Since racial classification is an anatomical conception, one might think that anatomy would play a large part in discussions of race. Actually the extent to which race has been discussed recently with almost no mention of anatomy is surprising. For example, Klineberg (op. cit.) in the section of his book devoted to the biological

¹ Reprinted by permission from Science Education, vol. 28, No. 2, 1944.

² References to the literature are cited at the conclusion of this article.

approach to race, pays little attention to fossil man, the antiquity of races, or the work of any recent anatomists.

The danger of discussing race without really trying to understand the anatomy of the situation is that one's examples will be irrelevant and one's logic faulty. As an example of faulty reasoning take the current statement that there are no important differences between races because all races intergrade. This is like saying that there are no differences in intelligence because there is a continuous distribution from the lowest to the highest IQ.

The best way to understand race is by a direct approach to the facts (Cobb, 1943), that is, to the study of fossil man, comparative anatomy, and the purposes and methods of classification. It is with these that this paper deals.

THE NATURE OF RACIAL CLASSIFICATIONS

The descriptions of the various races may be regarded as a series of guidebooks to the anatomy of man. Following the guidebook analogy, the content of the whole series of books equals present knowledge of comparative human anatomy. Since the subject matter of this series of books is continuous, the beginning and end of each volume is arbitrary, being determined by convenience. This guidebook series is a useful way of sorting and cataloging anatomical information, and the descriptions which the books contain were written to answer questions which arose in man's quest for knowledge and understanding.

The practical value of the anatomical descriptions which the books contain will become clearer as they are used. For example, we find that the volume entitled "Europeans" is especially useful because there are over 700 million people to whom this guide applies. The volume on "Mongoloids" includes over 600 million people. These two guidebooks alone describe two-thirds of the people in the world, and, therefore, they are the most useful ones we have. There is another book called "African Negro" which covers some 100 million. Then there are a number of slim volumes which describe types anatomically distinct enough so that it is useful to have separate guidebooks for them, but which are not numerous. Two such volumes would be called "Australian-Melanesian" and "Bushman-Hottentot."

Still there would be a great many people for whom no guidebook is available. Some of these are put in appendices or special chapters. Some have been shifted about when new information showed that they would fit better in a different volume. Migrations and subsequent crossing are creating new situations which the old volumes did not cover. The guidebooks, of course, will need constant revision to keep them up to date.

The usefulness of racial descriptions depends on the fact that the majority of the people in the world can be easily classified. There are intergrades between the types, but these people are less numerous than those to whom the descriptions apply. It should be remembered that classifications are not objective orderings of pure knowledge but are made by men for some purpose. Racial classifications are made by men who are trying to understand human anatomy. Since anatomical classifications have been made by many men in different periods, a brief account of the history of attempts to classify man will prove useful. In each era we will be concerned with purposes and methods rather than nomenclature, because the names of races are only symbols for describing results.

The earliest racial classifications were the result of the discovery that there was a variety of different kinds of men living in different parts of the world. These long antedate Darwin and the rise of evolutionary thought. Since these classifications were based on pictures and what travelers saw, they were superficial and used such traits as color and hair form only. Scientists saw that the populations in various parts of the world were different and sought to give a few characters by which the different peoples could be recognized. The purpose of these classifications was to give a key to the varieties of man. The method was to group like with like as any keen observer could do without special training. Since the vast majority of people believed in special creation and since the races of the world were so incompletely known that they appeared discrete, the races were described as separate species.

The second stage in the history of anatomical classifications arose in the latter part of the nineteenth century under the influence of Darwinian evolution. The purpose of the classification of this period was to describe the evolutionary history of man. The method was that of detailed anatomical comparisons. Bodies of individuals in different parts of the world were dissected. Great osteological collections were built up. It soon became apparent that words like "tall," "short," or "broad" led only to confusion, so various systems of measurement were introduced. These became the basis of modern physical anthropology.

This second era marks enormous advance over the first from the standpoint of both ends and means. However, the scientists of this era knew nothing of genetics or of parallel or convergent evolution, and few fossil men had been discovered. Also before the use of radioactive minerals, the geological time scale was very short. The age of the world was supposed to be only a few thousand years.

The present era is hard to characterize briefly, because it is difficult to keep a perspective on one's own time. The main differences between

this and previous eras lie in the abundance of all sorts of data and the kind of theoretical approach made possible by advances in biology and related sciences.

The primary aims of recent classifications are the same as those of the earlier ones. The first is to describe various people of the world in superficial terms. The purpose of this sort of description is to destroy intellectual isolationism. One wonders how many of our soldiers in the Far East had any idea of Polynesians, Melanesians, or aboriginal Australians before they went there. Some of these people seem very different and queer when one meets them for the first time. The best way to keep one's perspective is to have a good idea of the different races before being plunged into the midst of a foreign people.

Granted that it is desirable for citizens in a democracy with commitments all over the world to have some idea about the physical characters of the peoples of the world, how is this end to be accomplished? It is impossible to consider each of the 2 billion persons in the world. Therefore some system of sampling is necessary. It happens that mankind does divide into great groups, so that a relatively small number of individuals may substitute for the entire group. One Bushman looks more like the next Bushman than either looks like a European or a Mongolian. There is a great variation in each group. Races intergrade and mix. Nevertheless, at present there is no other practical method of obtaining some superficial acquaintance with what mankind is like from a physical point of view. The racial classification is a simple sampling system which allows a student to become familiar with the superficial physical characters of 2 billion people in a remarkably short period of time.

Existing races are the products of evolution, and a second aim of classification is to determine the relations of various races to fossil men and ultimately to other primates. The methods necessary for this purpose are very different from those which were adequate for the first. An understanding of comparative human anatomy is essential. Since fossils consist of bones and teeth only, knowledge of these parts is particularly important. Studies of the different proportions of the body are best carried out according to biometric methods. Genetics, particularly of the blood groups, is playing a larger and larger part in studies of the living.

The utility of the classification which has resulted from intensive anatomical and metrical studies is very great, and only a few examples can be cited here. It has made possible the determination of man's place in nature with an ever-increasing accuracy. It has served as an aid in historical reconstructions, as in determining the way in which the New World and Oceania were populated. It is of constant use in the anatomical laboratory where subjects of different races are dis-

sected. For example, the facial muscles of the European, African Negro, and Mongolian are quite different (Huber, 1931). This is so much the case that the student following the description of the European, which is in all the textbooks, may become confused when dissecting non-Europeans. There are numerous differences in the muscles and other soft parts, as summarized by Loth (1931), and in the proportions of the body and the skeleton (Martin, 1928). Pelvic shapes differ, and this has a practical application in obstetrics (Caldwell, Moloy, D'Esopo, 1934 and 1938). Limb proportions differ enough to affect the sizes of uniforms (Davenport and Love, 1921). Steggerda (1942) has shown the advantage of using separate height, weight, and age tables for different racial groups.

The more global our national interests become the more use will be found for knowledge of the anatomical characters of races. When there are more medical schools in China or Africa, undoubtedly anatomy textbooks will be written which apply more directly to these peoples.

In summary, the comparative anatomist or physical anthropologist cannot operate without racial classifications because these bring order out of the otherwise meaningless range of human variation. However, these are anatomical classifications which are used for anatomical purposes. Since the ends are anatomical in nature, the methods used are anatomical. There is no thought of leaping from anatomy to intelligence, language, or religion. A scientist takes the most direct route possible. If one wants to know about intelligence, intelligence should be measured, not cranial capacity. If one wants to know about language, language should be studied, not head form. One gets out of a mill only what goes in, although the form may have changed. When anatomy goes in, only anatomy comes out.

THE ANTIQUITY OF RACE

How shall we regard the races of man? Have they been relatively independent for millions of years or are they modern? It used to be thought that the races represented relatively fixed types, some of which were much more closely allied to the apes than others. If any of the living races is particularly primitive, it should be traceable far back in prehistoric time. How far back can the major living races be traced?

The skeletal remains which belong to the living races are found back through the Neolithic period (Polished Stone Age, earliest agriculture). Prior to that the situation was different. In Europe the round-headed people appeared near the end of the Old Stone Age. In Africa none of the early skeletal remains is typically Negro. In Asia Mongoloids seem to belong to late geologic time, but data are exceedingly scanty. As we go back in time, the picture is one of change.

The appearance of the modern races only a few thousand years ago is so sudden that theories have been developed to account for it. This sudden appearance may be partly illusory. Skeletal remains are all that are available, and the soft structures, which are not preserved, may have been more differentiated. Also data are lacking from vast areas, and so earlier representatives of the modern racial types may yet be discovered in these places. It has been argued that the races must be very old to account for the degree of difference seen today, but rather than follow logic alone let us see what the men were like who lived in the latter part of the Old Stone Age.

In Europe (several remains of the Aurignacian period), in Africa (Boskop, Springbok), in Java (Wadjak), and in Australia (Talgai, Cohuna),³ there have been discovered skulls and skeletons which all belong to the species of modern man, *Homo sapiens*. Their limb bones are typically modern. They had, on the average, larger jaws, teeth, and brow ridges than living men but were not beyond the range of variation of living races. Here there is definite evidence of modern man spreading out over the world before the living races are recognizable. All these fossils seem to be of approximately the age of the latter part of the last Ice Age, 20 to 50 thousand years ago. Of course, dating is subject to great error. At least it can be said that they are much older than the earliest finds that can be assigned to living races, and much later than the groups of ancient men to be considered.

In the Americas the evidence of early modern man is not as clear as in the Old World. The earliest finds (Minnesota, Lagoa Santa, Punin; see Roberts, 1943) differ from the later ones, and evidence seems to be accumulating that the men who first entered the New World some 25,000 years ago were a long-headed early type of modern man.

Here is a commonly accepted hypothesis which will cover the main facts of the last phases of man's evolution. Somewhere in the Old World about 50,000 years ago a generalized type of modern man developed. Variations of this type spread out over the Old World and, somewhat later, into the New. The groups that spread were small parties of hunters. It has been estimated that there were not more than 7 million people in the whole world at the hunting and gathering stage of cultural evolution. Therefore, these groups lived in extreme isolation. This isolation made an ideal setting for the development of the local varieties which are called races today.

Each of the major racial groups is characteristically located in one area of the world. The Whites, originally, were located in Europe, the Mediterranean area, and the Near East. The center of Negro de-

³ See Keith (1915 and 1931) for descriptions of these fossils. Hooton (1931) gives useful short accounts of fossil men, and the new edition of "Up from the Ape," now being prepared, will include all the important recent discoveries.

velopment seems to have been in the Congo and West Africa. The Bushmen occupied South Africa and formerly a good deal of East Africa as well. The Australian-Melanesian group occupied Australia, New Guinea, and adjacent islands. The Polynesians were late comers to the island area (the era of the great migrations seems to have started about A.D. 800). The Mongoloids were located in Eastern Asia and migrated into the Americas where they probably absorbed the earlier type of Upper Palaeolithic man.

If such an hypothesis is correct, as many scientists think, the area where the greatest mixing has occurred and which is hardest to classify should be the most central one, that is, India.

Dispersal followed by the establishment of local varieties has been called adaptive radiation. It has been shown to apply to numerous mammalian groups and seems to apply equally well to man (Howells, 1942). However, after the dispersion of modern man, the development of agriculture and the enormous subsequent increase in population soon changed matters. Childe (1939) has written a most stimulating book on the relation of civilization to population. The population of the world increased from some 7 million in the hunting stage to over 2 billion at the present time. As far as race is concerned, the result of this enormous increase has been the loss of biological isolation (Howells, *op. cit.*). Small numbers and isolation seem to be necessary for the establishment of new types. These conditions changed greatly after the introduction of agriculture and disappeared with the fabulous increase in population which followed the industrial revolution.

At present the characters of world population are being determined largely by mixture and differential birth rates. It is hard to see how new racial types can form under present conditions. It should be noted that the later phases of human evolution introduced new factors. While the earlier phases of man's biological progress can be treated just like those of any mammal, the later demand a knowledge of social factors. It is for this reason that social and biological scientists must cooperate in the study of man.

Granting that there was a dispersal of a rugged, generalized, modern man, from what type of man was he derived? There is no question upon which there is less agreement among students of human evolution. Some maintain that the modern type is of great antiquity (Galley Hill, Swanscombe skulls lend support to this view). Others feel that modern man is recent. The prevalence of other more primitive types until the latter part of the Ice Age, and the sudden spread of modern man at that time corroborates this hypothesis (to which the writer leans). However, there seems little doubt that the earlier Neanderthal men (Galilee, Ehringsdorf, Skhul 5, Steinheim; see

Weidenreich, 1943), and the *Sinanthropus* and *Pithecanthropus* types are ideal morphological ancestors for modern man.

These ancient men differ markedly from modern man. They have much larger and more massive faces, lower foreheads, smaller average cranial capacity, and their limbs show characteristic differences. Whereas the early *Homo sapiens* fossils, if alive today, probably could pass unnoticed in the New York subway, one of these ancient men would draw the attention of everyone. They were quite beyond the range of variation of modern man. However, they were true men. They had large brains (compared to those of apes), human faces and teeth, and human limb bones. They walked upright as we do, and in their morphology are infinitely closer to modern man than they are to any ape.

Ancient man spread out, just as early modern man did. His remains have been found in Europe, Russia, China, Java, Palestine, and Africa. Apparently, ancient man never reached the New World or Australia.

To which of the living races are these ancient fossils particularly closely related? To none. The major races gained their individuality long after the time when the earliest representatives of modern man lived. Before these earliest modern men there is a morphological gap, perhaps bridged by a skeleton from Palestine.

If any of the modern races is particularly primitive, its remains should be found in early strata and should be proportionately more numerous in more ancient deposits. The only one of the modern races of which this would be at all true is the aboriginal Australian. The Wadjak, Cohuna, Talgai series of fossils seems to offer connecting links between early modern man and the Australian. Also of living men the Australian seems to have more in common with generalized early *Homo sapiens*, although the living Australians have evolved along lines of their own. They simply seem to have changed less than the others. Even the aboriginal Australian is definitely a modern man and lacks the peculiarities of the face and limb bone which characterize ancient man.

Since the existing races have a common ancestor in early modern man and since racial differences cannot be traced back even as far as ancient man, what possible purpose is there in comparing living races directly to the apes? Let us see how long a history of common ancestry the living races have compared to the time they have been separate. Most students of human evolution feel that man must have had an independent course of evolution since at least the end of Miocene times. Many (Clark, Gregory, Hooton, Keith, Osborn, Wood-Jones) would add millions of years to this. Early modern man lived from 25 to 50 thousand years ago (considering the Pliocene period to have lasted 6 million years, the Pleistocene 1 million, and Recent 25 thousand). Let us be generous and say that the races

were distinct for 50 thousand years, although all known skeletons of definite racial affiliation are not over 25,000 years old. Taking a minimum for the length of time that man has been separate from the apes, and a maximum for that during which the races have been distinct, the time during which all living people have shared a common human ancestry is a hundred and forty times that during which any race has been independent. To put the matter conservatively, every living race has had at least 100 times as much of its human ancestry in common with all the other races as it has had alone. Since what divergence has taken place is all after the attainment of essentially modern morphology, it is hard to see how any of the living races can be considered significantly more primitive than the others. None of them is close to ancient man, let alone the apes. All are very modern products of the slow process of evolution.

The genealogical tree which appears in many textbooks is completely misleading. In this tree the races appear to have been separate for a very long period of time, for most of the Pleistocene period. In fact separate races are indicated as old as any definitely dated skeleton of man. Then, too, the time scale is completely misleading. The Pleistocene is indicated as longer than the Pliocene and the Pliocene than the Miocene. Omitting time or using a changing time scale is very confusing, and is such a frequent feature of genealogical trees that it deserves special mention. Only one of eight trees which I have before me keeps the time scale even approximately correct. The effect of seeing such a tree is that the student gets the impression that the races have been separate for approximately one-third of human history. If this were true, there would undoubtedly be great differences between them. One should never use a chart on which the scale changes or is omitted, because the student inevitably gets the wrong idea. It is impossible to put both the divergence of the human line from the ape and the differentiation into modern races on any single chart. If the time from the divergence of human and ape stems to the present be represented by an ordinary pack of 52 playing cards placed end to end, all racial differentiation would be on less than half of the last card. This is one of the most important facts of human evolution, and the use of genealogical trees with changing time scales, on which the importance of all late events is exaggerated, has obscured it almost completely.

The practice of comparing individual races directly to the apes should be abandoned. It is usually done with the best intent to show that, although the White is more like the ape in one character, the Negro is in another. But what this practice actually does is to keep alive the idea that it is reasonable and scientifically defensible to compare living men with living apes for the purpose of arranging

racess in some hierarchical order. What meaning have these comparisons when the races have nearly all their ancestry in common?

Unless it could be proved that the living races differed greatly in their relations to ancient man, it is pure waste of time to compare them individually to the apes to determine which is the most primitive. It is sound biological practice to compare closely related animals first. In order to determine the relation of a Shetland pony to a Shire horse, no one would compare each to *Eohippus*. It is reasonable to compare living men to apes to determine how great is the anatomical divergence between mankind as a whole and apes. Similarly, a modern horse might be compared to *Eohippus* to see how great a change there had been in horses since Eocene times.

Different characters are appropriate when discussing different stages in man's evolution. Since racial differences are small and recent, they are of no use in discussing remote phases of human evolution. Misunderstanding of this point has caused so much confusion that it is worth giving two illustrations. Long-headedness is often spoken of as being a primitive character. Since some gorillas, particularly from the Cameroons (Randall, 1943), are round-headed, it has been argued that long-headedness is not primitive. Now early modern man was long-headed, and the round-heads, which appear later in the fossil record, seem to have been derived from the early long-heads. A character which changes so rapidly is of no use for comparisons with gorillas. Note that the word "primitive" changes its meaning constantly. One speaks of primitive characters meaning those of (1) early modern man, (2) ancient man, or (3) apes, and in each case the characters are different. How vitally a little knowledge on this point is needed is well illustrated by a pamphlet which was published recently. The authors wished to prove the unity of the human race. One of the two illustrations which they picked was the number of teeth. The human dental formula is the same as that of the apes and Old World monkeys. The other illustration (the number of bones and muscles of the foot) is equally irrelevant. The unity of the living races is proved by the anatomy of modern man, not by characters which are shared with hundreds of nonhuman primates and had their origin at least as far back as the basal Oligocene.

If the fossil record showed that the groups which are now recognized as races had been separate as early as the Oligocene period, then the dental formula would be a relevant consideration. The interpretation of the fossil record is the crux of all thinking concerning the antiquity of race.

In summary, the most direct and important evidence there is on the antiquity and relations of races comes from the fossil record. This evidence is being augmented constantly by new finds. Therefore

we are sure that the continued study of fossil man will give clearer insight into this problem.

THINKING ABOUT RACIAL PROBLEMS

Up to this point I have tried to present a view of racial classifications which stresses ends and methods, and have tried to interpret the fossil record to give a perspective on the antiquity of races. Naturally, in a short paper it is impossible to do more than indicate a point of view.

I do not believe that an understanding of the anatomy of race will settle the social problem of racial discrimination. I agree entirely with Benedict (1940) that this is only one part of the more general problem of social discrimination. Nevertheless, if racial classifications are to be discussed at all, it is necessary to try to understand them first, and then to evaluate. Making serious errors is the price which one pays for discussing race, without trying to understand the anatomical situation. One can imagine Nazi biologists laughing with delight if pamphlets containing misstatements are translated and sent to Germany after the war. There is no easier way to discredit a whole point of view which one does not like, than finding one or two glaring errors. Therefore, if we are to discuss racial matters with the Nazis, we had better be right.

The following section of this paper is devoted to the analysis of a series of problems which have risen repeatedly in recent discussions about race. In each section my aim will be to try to clarify thinking, not to supply final answers.

HEAD FORM AS AN INDICATOR OF RACE

It has been said recently that the form of the head (cephalic index) is useless as an indicator of race. This is claimed because both broad- and long-heads appear in Negroes, Mongolians, and Whites. Now instead of taking an absolutist point of view, let us consider the history of Europe for a moment. The early men were long-headed. The migrations of round-headed people came from the east. Some of these migrations are historically documented and recently Candela (1942) has shown how certain ones explain the distribution of blood-group B in Europe. The shape of the head is one, and only one, of the anatomical features in which these migrants differed from the earlier peoples. In considering the changes which have taken place in the population of Europe, the cephalic index is useful. From the pragmatic point of view, it is quite irrelevant whether the index is useful in any other problem. We are not trying to prove whether the cephalic index is good or bad in an absolute sense, but are merely asking whether this index aids in unraveling a small part of the complex history of Europe.

There is nothing magical about the shape of the head. Sometimes, along with other characters, it is useful in racial classification. The point which should be stressed is that head form is not good or bad in an absolute sense, but useful or not useful, in a particular situation. Without knowing the situation, one cannot judge.

The pragmatic point of view is essential both in judging single characters and whole classifications. For example, it has been said that racial classifications mean very little because the races intergrade so that all people cannot be classified. From the practical point of view, the question is whether enough people can be easily classified so that racial classification is useful.

GENETICS, PHENOTYPICAL AND GENOTYPICAL CLASSIFICATIONS

Geneticists and others have suggested that the classification of man should be based on the primary units, the genes. The classifications we have now are based almost entirely on phenotypes, that is, adult structure.

It should be remembered that, as mentioned previously, the classification of adults is now useful to anatomists and many other people. The obstetrician cannot wait until the genetics of pelvic type is known before making a delivery.

Since at the present time there is no genetic classification of man, the main question seems to be whether future knowledge of gene-frequency distributions will substantiate present classifications. My belief is that it will, as far as the major groups are concerned, but that subraces which do not breed true and are found only in mixed populations will never be reconciled with genetic theory. The blood groups are the only traits whose mode of inheritance is known and which have been studied extensively in many parts of the world. The distribution of the blood groups shows marked regional differences. For example, group O is very frequent among American Indians, and group B among the Chinese. That the same genes are present in all races but in different frequencies seems probable. Only the future will tell, and the sooner the genetic information is available, the better for all.

THE MEANING OF THE WORDS "RACE" AND "SPECIES"

Some writers have tried to settle racial problems by substituting another word or words. This represents the opposite pole from that stressed in this paper. We have already seen that "primitive" may have a variety of meanings. After all, words are only symbols, and it is ends and methods which are the framework of science. If people want to use other words instead of "race," of course they have a right to do so. The danger is that changing words may appear to solve problems, when it only obscures the fact that we are doing the same things as before. The word "race" has as many different meanings

as there are methods used to sort races. Some groupings are based on much knowledge and some on very little. Some are undoubtedly nonsense from any point of view. Vocabulary can be multiplied prodigiously to try to reflect each change in method, or we can simply say that the meaning of the word in any given case depends on the operations performed in the creation of that race. The operational point of view (Bridgman, 1936) keeps one's attention constantly on knowledge and methods, and off distinctions that have only a verbal basis.

The importance of emphasizing operations actually performed is well shown by the word "species." It has been stated recently that all living men belong to one species because all the races can interbreed. Now at least as early as 1863 (Zuckerman, 1933) it was known that groups of monkeys classed in different genera would interbreed. If one pauses to think that the primates have been classified in museums and anatomical laboratories, it is obvious that tests of fertility cannot have been one of the operations actually performed. The species of primates are natural groups which are distinct, that is, every individual can be classified as belonging to one. Species are the smallest natural groups about which this is true, because, since subspecies (races, varieties) intergrade, many individuals fit equally well in more than one group.

Existing races of man are called "races" and not "species" because their characteristics intergrade. If there were no intergrades between Bushmen and Europeans and if they were classified in some museum using the same methods used for monkeys, they would be put in separate species. As the classificatory system is now used, lack of intergradation, and not inability to breed, is the characteristic actually used. The history of how the idea of interspecific infertility arose is worth considering because it shows the necessity for the operational point of view. Species of monkeys were seen living in the same locality and no hybrids were found. Since it was assumed that any monkey would mate with any other (which is not true), the fact that no hybrids were found proved that species were not able to interbreed. Therefore species were thought to be mutually infertile groups. So a conclusion, which is now known to be false, because a criterion of a group which actually was defined entirely differently. If species had been defined in terms of what people did in separating them, inability to cross would never have been considered a specific character for primates.

METHODS OF CLASSIFICATION AND PURE RACES

All races of man are mixed, and within any racial group there are always individual variations. After all, even monkeys of the same subspecies collected in the same locality vary considerably (Schultz,

1926, 1937; Washburn, 1942), so there is no reason to expect greater homogeneity in man. In the primates as a whole, there appear to be no pure races in the sense of types, such as some strains of laboratory rats or mice, which are held constant by inbreeding and removal of any deviating individuals. The human situation is more complex than that of other primates because human wanderings and migrations have been so much more extensive. Also human social habits, such as trade, war, and slavery, introduce an entirely new set of factors.

Mixing has played a much greater part in the physical history of man than it has in the evolution of nonhuman primates. In this sense it is correct to say that there are no pure human races.

However, the word "pure" has been applied to races created by two different methods, and it is very important to keep these methods separate in one's thinking. For example, let us consider the construction of the races frequently called "pure" aboriginal Australian and "pure" Nordic.

In the case of the Australian aboriginal, "pure Australian" means the Australian black as he is observed to be, without obvious mixture with other races. The characteristics of the type are derived from the study of the population. The range of variation in each character is charted. The children belong to the same group as their parents, that is, the race breeds true within the limits of the parental population.

"Pure Nordic" means a group of people who are tall, long-headed, blond, blue-eyed, and who have the numerous other traits which are attributed to this race. Do Nordics breed true, that is, will the children of Nordic parents be Nordic? The children may be too short, too round-headed, too dark-haired or dark-eyed to be classed as Nordics. From this it is clear that the group which has been selected as pure Nordic is pure in phenotype only. How was the Nordic race created? Individuals were seen with the characteristics attributed to the race, and then the pure race was postulated, and the observed situation described as the result of mixture. In the case of Nordic the meaning of "pure" lies in the operations performed to construct the race, that is, in the creation of an imaginary type, which is not found. In the case of the aboriginal Australian, "pure" means a population which exists, which is studied directly, and which is without obvious admixture. This does not mean that there never was any crossing, but simply that our methods cannot detect any.

The descriptions of some races, such as the Australian, are based on the study of populations. Other races, such as the Nordic, are created by selecting individuals from a population and then describing the selected group.

The great interest in racial purity has taken attention from the fact that some of the mixed races cannot even be demonstrated as actual groups of living, breeding human beings. Each race is worth

no more consideration than the operations which created it. Whether we call the Australian race "mixed" or "pure," the same operations are used to create our description. Whether the Nordic race is called "mixed" or "pure," it is still an arbitrarily limited creation of the imagination. Only when one studies how races are created and in what situations these concepts are useful, does the vast difference between Australian and Nordic become apparent. The crucial point is, not that the Nordic race is mixed, but that there is no evidence that there ever was a group of human beings who had the characters of Nordics, and who passed these traits along to their children.

The first step in racial analysis is to find out whether there is a self-perpetuating group of human beings who actually have the characters of the race. The second is to see what methods were used to describe and delimit the race.

It is only by knowing how particular races are described that one can decide which ones are useful categories and which are useless. Below is an analysis of one race.

Race: Pure Nordic.

Location: Nowhere.

Method: Imagination.

Result: Nonsense.

SUMMARY AND CONCLUSIONS

The conclusions of this paper may be briefly summarized as follows:

1. Racial classification is an anatomical concept and is useful for anatomical purposes.
2. The fossil record shows that the living races are extremely modern from a biological point of view, having had most of their human ancestry in common.
3. Keeping purpose and method constantly in mind removes much of the confusion which exists in current thought about race.
4. To understand race, a knowledge of human biology is necessary. Because words are only symbols, a knowledge of the things symbolized is imperative for proper understanding. It is here that the science teacher has a great contribution to make in both fact and method.

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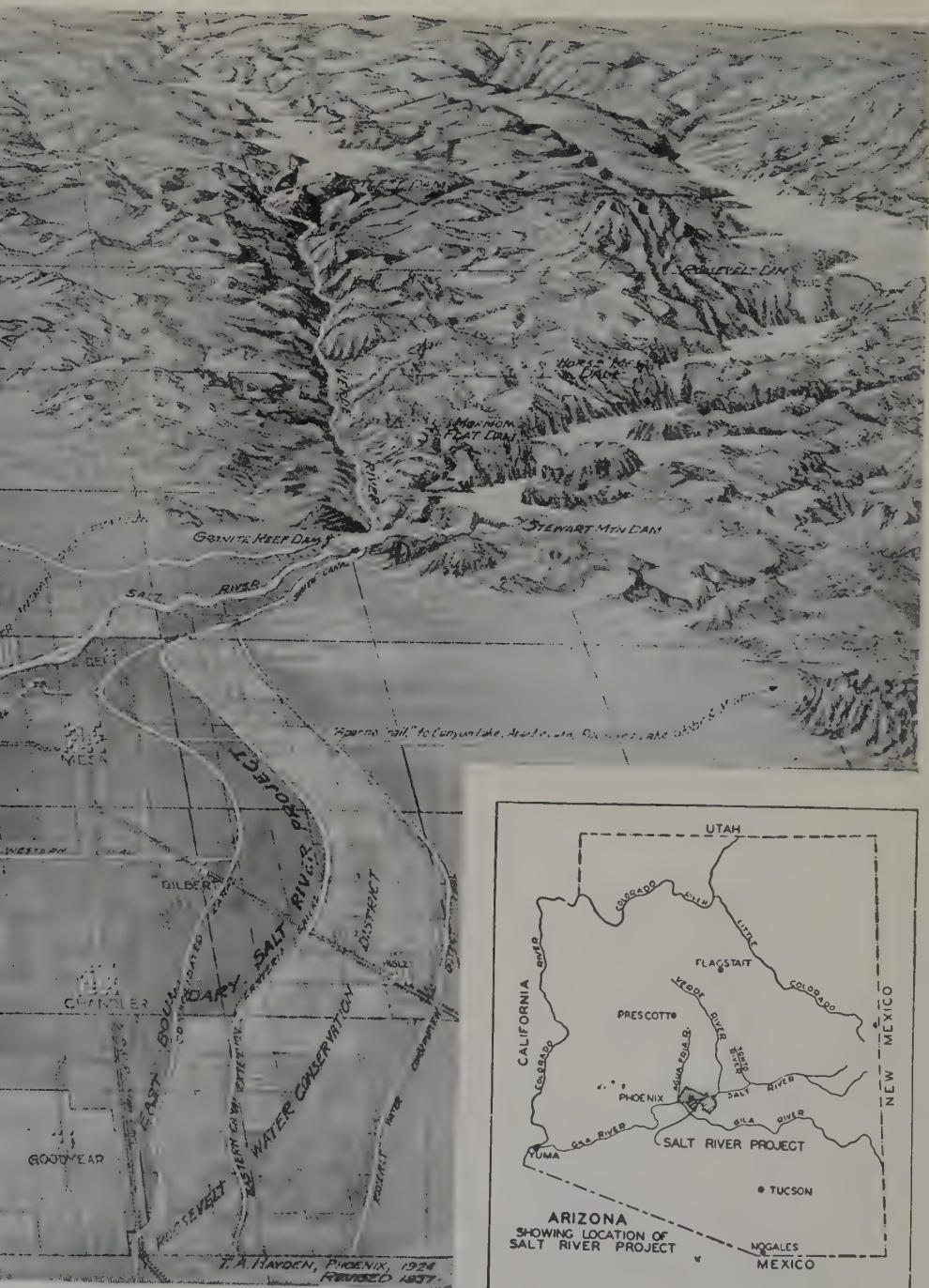
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PRESENT-DAY IRRIGATION IN THE SALT RIVER VALLEY, SOUTH-CENTRAL ARIZONA.
The prehistoric irrigation project covered the central portions of the same area.



A UNIQUE PREHISTORIC IRRIGATION PROJECT¹

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[With 5 plates]

Intentional diversion of water from its natural channels, for the purpose of irrigating regions of inadequate rainfall, is widespread in time and space. Usually, however, it is thought of as something of an innovation and as of more or less local significance.

Inhabitants of humid areas are likely to underestimate the very considerable portion of the earth's surface where the natural supply of moisture is insufficient to meet the needs of agriculture and other human economic requirements. In the United States alone virtually one-half the land area, westward from its longitudinal center, is arid or semiarid, as are vast areas in Mexico and South America.

Much of the Old World, particularly those countries adjacent to the Mediterranean and in the Near East, where ancient civilizations originated and flourished, are arid and desertlike. The valleys of the Tigris, the Euphrates, and the Nile are classical examples of the dependence of life on the natural or induced overflow of these great river systems.

The importance of water—and the tragedy of too much or too little—are reflected in the early literature, both sacred and profane, from the time of the Babylonian poet-philosophers downward through the centuries. An outstanding record of excessive rainfall is that of the Noachian flood; a minor example may be found today in the rain belt where someone, perhaps with a picnic in prospect, hopes that tomorrow may be fair! In between, the annals of virtually every people contain legends of floods and consequent devastation. Because of insufficient rainfall Moses, leading the Children of Israel back to the homeland, smites the rock, that they may drink; and the Arab

¹ Address of the retiring president of the Ohio Academy of Science, delivered at the annual meeting of the Academy held in Columbus, Ohio, May 5, 1944. Reprinted by permission from *The Ohio Journal of Science*, vol. 44, No. 5, September 1944.

sheik bespeaks the compassion of Allah in the matter of the failing desert spring.

The crude methods of conserving water for domestic and agricultural use employed by present-day Pueblo Indians of the arid southwestern United States are a matter of common knowledge. Natural springs and water holes are seasonal sources; rivers which carry water through the year serve those living adjacent thereto; but by far the greater number of inhabitants must conserve rainfall and storm water from the mountains and the high mesas in natural depressions, converted into reservoirs by means of dams and other artificial modifications. While in some instances ditches lead from these to nearby fields and gardens, the Indian women usually must carry water in jars for hand-irrigation of their meager crops. Archeological investigation has shown that, with few exceptions, surprisingly similar methods were employed in prehistoric times in the same general area.

This paper, however, is concerned with the historic aspects of irrigation only as a frame or background for an even more romantic phenomenon—prehistoric irrigation in the New World!

Although a matter of record, it is not generally known that in south-central Arizona, long before the discovery of America, the native aborigines had perfected an impressive system of irrigation, which made possible the successful practice of agriculture over a period of several centuries. This system has been referred to as a "million-dollar project, constructed with nothing more than rude stone hoes and wooden digging sticks."

Residents of Ohio and adjacent parts of the Middle West, where the civilization of the so-called Mound Builders has been made known through exploration of their ancient tumuli, may not find this so incredible; but to many persons, accustomed to thinking of all prehistoric peoples as mere savages, the phenomenon is certain to be something of a surprise.

A glance at the map of the southwestern United States will serve to set the stage for the human drama which now unfolds itself. It will be noted that the State of Arizona, youngest of the American commonwealths, is bounded on the north by Utah and Colorado; to the east is New Mexico, and to the south is old Mexico. The great Colorado River, beyond which is California, forms Arizona's western boundary.

Traversing the State from northwest to southeast are southern extensions of the Rockies, and the high plateau where today live the Pueblo Indians and where in ancient times lived their predecessors, the prehistoric Pueblos and the so-called Basket Makers. To the west and south of the mountains is the Arizona desert region of scant rainfall, where, because of its much lower altitude, relatively high temperatures prevail.

In south-central Arizona is the city of Phoenix, capital and metropolis of the State. From the mountains and high plateau toward the east come two rivers—the Salt from the northeast and the Gila from the southeast. They converge just west of Phoenix and find their way, as the Gila River, to the Colorado and the Gulf of California.

The State of Ohio sometimes is referred to as the land of the Mound Builders; the valleys of the Salt and the Gila, particularly the region of which Phoenix is the hub, may with equal justification be referred to as the land of the Canal Builders! Here we have the double phenomenon of an area of considerable extent, by nature arid and uninviting, which, for several centuries in prehistoric times, was made to "blossom as the rose"; which then reverted to its natural aridity; and now, once again, has become one of the more fertile and productive regions of the continent!

The visitor to Phoenix need walk but a short distance outside the city limits to come upon one or more ancient irrigation canals. Accompanied by a guide familiar with the terrain, he will be able to trace a number of others, and will learn that prior to their partial obliteration by present-day agriculture, some 125 miles of main irrigation canals were existent in the Salt River Valley and perhaps half that mileage in the valley of the Gila. Many of these measure as much as 30 feet between their crowns and reach depths of 10 feet or more. Even at this late date some of these may be traced for as far as 10 miles.

The canal system in the Salt River Valley consisted of several independent units, or main canals, each with many branch canals and ditches. Intakes of the main canals were far enough upstream to provide sufficient "fall" for successfully irrigating their respective areas. The lateral branches, most of which long ago were obliterated through erosion and silting, must have aggregated hundreds of miles.

An aerial survey of the valleys of the Salt and the Gila was effected in 1930 through the cooperation of the Smithsonian Institution, the United States Army, and certain authorities in Arizona. This aerial reconnaissance, during which the region was accurately photographed and mapped, was followed by a ground survey under the direction of Phoenix city archeologist, O. S. Halseth. As a result of this dual survey, what admittedly is the only true irrigation culture in prehistoric America has become a matter of record.

This brief outline of prehistoric irrigation and agriculture in Arizona should elicit a desire on the part of the reader to learn something of the people responsible for their development. Who were the ancient Canal Builders? Spanish padres and adventurers from old Mexico, who came into the region toward the close of the seventeenth century, perhaps were the first white men to ask this question. Naturally, they sought the answer from the native Indians,

the Pimas, resident in the district, and received the reply, "Ho-ho-kam!" meaning nothing more nor less than "those who have vanished." The canals and the adjacent ruins already were abandoned and ancient as far back as Pima tradition carried.

Thanks to archeological researches sponsored by the University of Arizona, the city of Phoenix, Gila Pueblo of Globe, Arizona, the Bureau of American Ethnology, and other agencies, the erstwhile forgotten annals of the Canal Builders in great part have been recovered and recorded. This is particularly true of the material aspects of their culture.

As indicated by their numerous irrigation canals, the Hohokam peoples were agriculturists. In and adjacent to the Salt River Valley there are the ruins of some 20 ancient farming communities, each with its central communal adobe structure, with perhaps half that number in the valley of the Gila. The most impressive of these ruins in the Gila drainage is the noted Casa Grande, now preserved as a national monument.

Outstanding in the Salt River Valley is Pueblo Grande, a part of the park system of the city of Phoenix, located just east of the city limits. Here the enterprising capital city of Arizona has erected an anthropological laboratory in which is housed a museum of the Hohokam culture, workrooms and laboratories, accommodations for visiting anthropologists and students, and living quarters for the director of the laboratory, who also has the title of city archeologist. During the months of February and March 1944 the author had the pleasure of being a guest at the laboratory, with unusual opportunity for studying the Hohokam culture at first hand.

A brief description of Pueblo Grande ruin and its adjacent farming community will serve as an index to the culture as a whole, which is quite homogeneous throughout the area of its occurrence.

The ruin of the Pueblo Grande community structure, adjacent to the laboratory, is a more or less rectangular truncated mound of earth and stone, some 150 feet in width and 300 feet in length with an approximate height of 30 feet. It has been partially excavated by Director Halseth and his associates and students, and proved to consist of a large number of rooms or compartments of varying sizes. The walls and partitions are constructed of flat stones and boulders imbedded in adobe clay, with roofs of logs, poles, brush, and adobe. Enclosing the structure, and built from similar materials, was a high wall. Entrance to the resulting compound presumably was by means of ladders. The structure and its compound served the community as a granary and storehouse for their corn, beans, squash, and other products and possessions, and as a safe retreat from marauding tribesmen from outside their borders. The great size of the structure

and its many rooms are accounted for by the fact that adobe construction was at best only temporary or semipermanent, and required frequent repairs, abandonment of certain parts, and the building of new units.

Outside the compound and adjacent thereto were the cultivated fields, comprising many acres. Here, too, the people lived, their domiciles being merely crude shelters of poles and brush, their floors somewhat below the surface of the ground—a type of domicile known to archeologists as pit houses.

It would be unfair to judge the culture of the Hohokam peoples solely by their unassuming dwellings, for it should be remembered that in the mild climate of their country they could be, and were, people of the great outdoors. Their amazing system of irrigation canals and the resulting agricultural development, together with their pretentious communal centers and their ceremonial ball courts, are sufficient to place them on an advanced plane of culture; nor should one overlook their admirable development of the minor domestic arts. While little of a perishable nature has survived the destruction wrought by time and the elements, their utilization of clay, stone, shell, and other time-resisting materials, is in keeping with their major accomplishments. The potteryware of the Hohokam, particularly, is exceptional, and many fine examples of pots, jars, vases, and bowls, of pleasing form and decoration, have been recovered. Equally impressive, if not as artistic, are the numerous metates and manos, for grinding corn and other grains and seeds, while their stone axes are among the finest known. Beads, pendants, bracelets, and necklaces of shell and other materials are much in evidence, and turquoise occurs sparingly. Chipped flint projectile points and knives, while often of good workmanship, are much less abundant than in the Middle West, obviously for the reason that the Hohokam were mainly agricultural and only moderately dependent on wild game for food. Tobacco pipes are of very infrequent occurrence, as contrasted with Ohio, where large numbers are found in the ancient mounds and burial sites. Tobacco doubtless was ordinarily smoked as cigarettes.

While archeologists specializing in the culture are virtually agreed that the Hohokam came into the Salt and Gila Valleys at or slightly before the beginning of the Christian Era, there is no definite evidence as to their origin. There *is* some evidence of affinity with the lesser-known Mogollon and Cochise cultures to the south, and of contact with the Pueblo peoples to the north, but the full significance of these remains undetermined.

Fortunately, however, the approximate period of their occupancy and the probable time and cause of their disappearance from their

homeland in Arizona now are known. The techniques employed in discovering and recording a major part of the story of the Hohokam peoples, after the lapse of centuries, not only is a romance in itself, but is an example of the efficiency of the methods of archeology as well. Here, briefly, is the story.

Earlier in this paper it was stated that the Hohokam are believed to have come into south-central Arizona around the beginning of the Christian Era. At this point it may be stated that they disappeared from the region around A. D. 1400, some three centuries prior to the arrival upon the scene of Spanish explorers and adventurers from old Mexico. For the evidence on which this chronology is based, we must turn momentarily to another region and another people—the Pueblo nations of the high plateau and canyons.

Here in a region of evergreen forests, the ancient ruins of the Pueblo peoples actually have been dated by means of tree-ring counts, a technique developed by Dr. A. E. Douglass of the University of Arizona. Details of this immeasurably important development cannot be given in the limited space of this paper. It is one of the romances of American science. (See bibliography.) Suffice it to say that most of the major ruins and scores of minor ones in the Southwest now have been dated by this method, and that the chronology of the region has been carried back to the first century A. D.

As a result of the tree-ring method of dating, those ruins in forested areas adjacent to the Hohokam country show significant changes through the centuries in types and decorations of potteryware and in virtually every aspect of their material culture; and since there was more or less of trade and barter as between the two areas, the finding in a Hohokam site of a Pueblo pottery vessel of, let us say, the period of A. D. 1000, is suggestive to say the least. Multiply such individual instances by any reasonable number, and at least a near-contemporaneity is the result. Although the Hohokam country is virtually lacking in large trees, through such analogy and comparison its ruins are dated.

Finally, when all evidence of Hohokam activity ceases, and no further objects known to pertain to other cultures appear in their ruins, it is logical to assume that their career as a people was ended. Such conditions are found to obtain not much later than A. D. 1400.

The disappearance of so advanced a people from a region which they had converted into an admirable place of residence was due to two major causes. One of these is disclosed in a brief consideration of the present-day situation.

In the 1870's Mormon settlers appeared in the Salt River Valley and began clearing out ancient irrigation canals and constructing others. In the ensuing years this initial enterprise has grown by

leaps and bounds, with some 400 square miles of terrain, requiring annually 1,000,000 acre-feet of irrigation water, now under cultivation. Thus the land of the ancient Canal Builders once more has come into its own, and the Salt River Valley—the Valley of the Sun—with its great citrus groves, date orchards, farms which produce as many as three crops annually, and subtropical plants and flowers growing in great profusion, is indeed an oasis in the desert.

In view of the fact that this transformation is due entirely to irrigation, it may appear contradictory to suggest that irrigation was the principal cause of the downfall of the Hohokam peoples. The Salt River Valley is underlaid with a "volcanic pocket" of clay or marl which is virtually impervious to water. According to estimates of the Salt River Waters Users Association, one-fifth of the total irrigation water enters the ground as seepage, and builds up the water table at the rate of from 3 to 5 inches each year. During the period from 1870 to 1920, when irrigation was much less intensive, one-third of the area under irrigation was rendered unfit for cultivation as a result of accumulated seepage and attendant alkalinity. Under present-day intensive irrigation, the entire area, within a comparatively short time, would be little short of an alkaline bog. This threat now is averted by periodic flooding to eliminate alkali and by using a battery of electric pumps for the purpose of removing surplus water—some 300,000 acre-feet annually.

The ancients had no drainage facilities, pumps or otherwise. The result was inevitable; surplus water and alkalinity, water-logged soil, and dwindling productivity. This is evidenced by the fact that exploration of the Pueblo Grande ruin demonstrated that the floors of granaries and storerooms had repeatedly been elevated in an effort to keep them above the water-logged surface of the ground.

An additional situation, which may have been the coup de grace of Hohokam survival, was the constant threat from marauding nomadic tribesmen from the plateau areas. It is known that from early historic times the agricultural peoples of the valleys were frequently raided by the Navajo, the Apache, and other predators who made bold to reap where they had not sown, and there can be but little doubt that the peaceful Hohokam peoples, throughout their sojourn in their chosen country, were forced to contend with similar hostile incursions. Faced by such handicap, and seeing their once fertile acres gradually transformed into water-logged and alkaline wastes, it was inevitable that their numbers must decline to the point where a few hungry stragglers either found refuge with other tribes or passed entirely from the picture.

Today there remain only the old canals and the ruins of once impressive communal structures—mute evidences of a people who

had carried the human experiment, through trial and error, to a level which must command the admiration of all discerning men; a people who, but for a natural calamity with which they could not cope, and because of the rapacity of unscrupulous and hostile neighbors, might have borne the torch of civilization to undreamed-of heights. The construction of a million-dollar irrigation system, representing a high degree of engineering skill, attests to their energy, strength, courage, and initiative.

Our culture of today is complex, while theirs was simple; but who would venture to say that ours is "higher" or better? We, as were they, are still beset with the threat of natural calamity, and by "man's inhumanity to man." The first of these is nothing as compared to the latter, which precipitated all mankind into a holocaust such as the world never has known, the aftermath of which conceivably might be more disastrous than the titanic struggle itself.

The only criterion which justifies an assumption that one culture is higher or better than another, is proof that it provides a larger measure of cooperation, usefulness, spirituality, morality—and human happiness!

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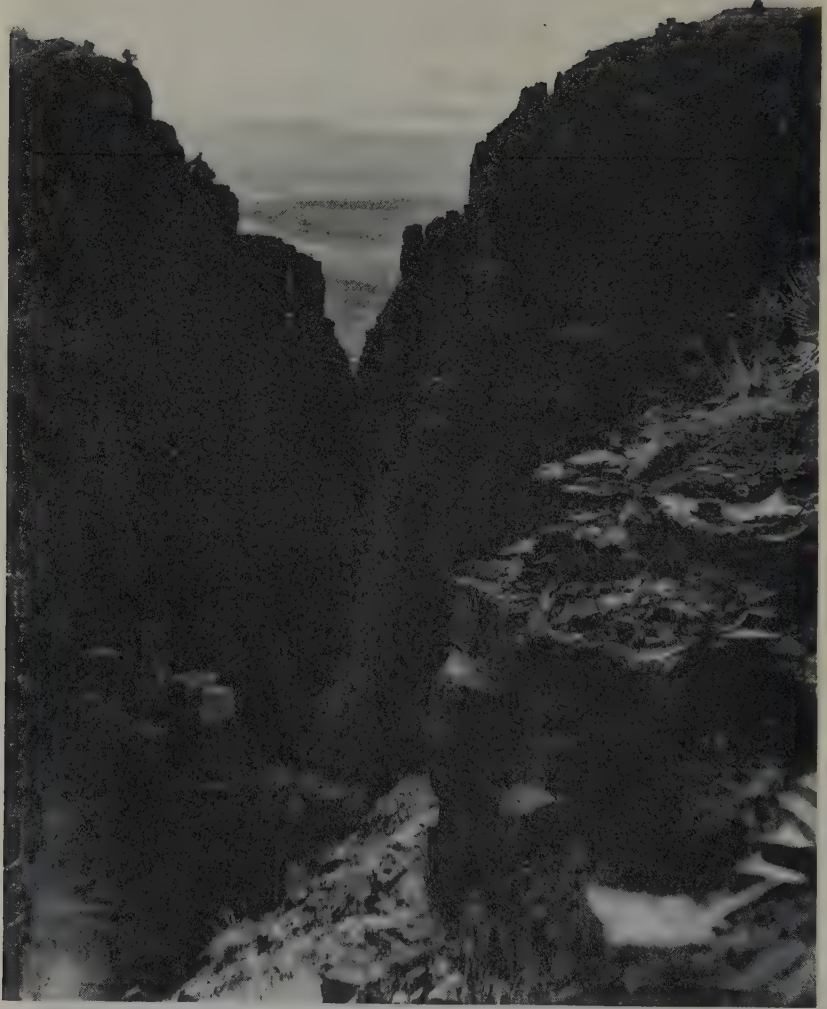
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TYPICAL LANDSCAPE OF UNIRRIGATED SECTION OF SALT RIVER VALLEY.

(Photograph by Odd S. Halseth.)

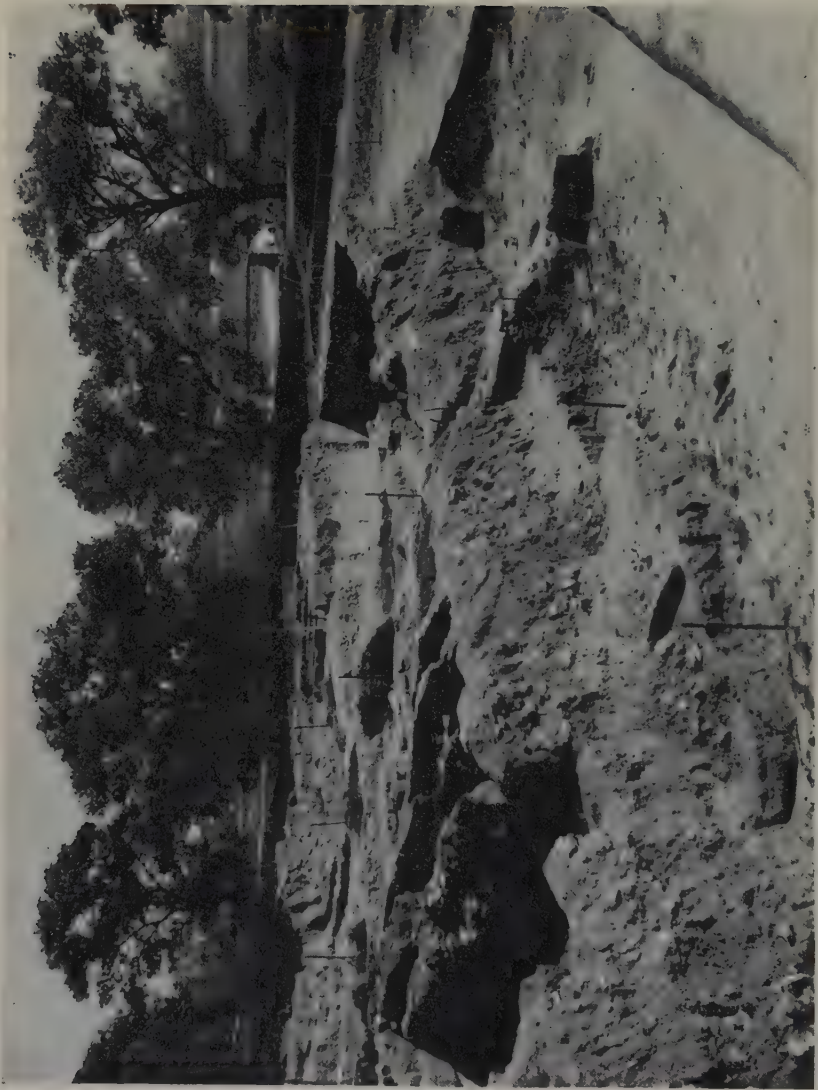


VIEW OF MOUNTAINS FROM APACHE TRAIL, EAST OF PHOENIX.
Upper course of Salt River, source of irrigation water, seen through the gap. (Photograph by Odd S. Halseth.)



SECTION OF A PREHISTORIC IRRIGATION CANAL, JUST EAST OF PHOENIX.

(Photograph by Odd S. Halseth.)



SMALL SECTION OF PUEBLO GRANDE RUINS, PARTLY EXPLORED.
(Photograph by Odd S. Halseth.)

CONCEPTS OF THE SUN AMONG AMERICAN INDIANS¹

By M. W. STIRLING

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[With 6 plates]

Webster's dictionary defines the sun as "The luminous heavenly body, the light of which constitutes day, and absence of the light of which constitutes night." Astronomers might object that this rather oversimplifies the subject, but it has the advantage, at least, that primitive people all over the world would agree with it.

The American Indian was concerned much more with the effects of the sun than he was with the nature of the sun itself. Apparently the average man did little if any thinking about the matter. He accepted, vaguely, explanatory information as given in myths. Such inconsistencies and conflicts as might appear to a person of another culture did not bother him since most of it was in the realm of the supernatural. He interpreted the universe just as it appeared to him. The earth was a flat disk covered with a hemispherical blue dome or firmament which fitted over it like a bell jar. Attached to it or moving across it like flies on a ceiling were the various heavenly bodies. These as a rule were personified.

We might infer from the sun myth of the California Indians that, because Coyote stole the sun and put it in a sack which he carried off on his back, the sun was considered to be of a size that a man could carry. However, in the same myth, when Coyote paused to dig up a worm, Mount Diablo was formed by the back dirt. In fact, in Indian myths generally, there is a rather complete abandonment of all dimensional concepts. As supernatural beings, the cricket can engage in combat with the elk on equal terms.

We all remember the childhood pastime of asking "How big does the moon (or the sun) look to you?" "Does it look as big as a dime or as big as a dinner plate?" We judge size by eye, only through comparison with some object of known size, so that the sun and the moon in

¹ The thirteenth Arthur lecture, given under the auspices of the Smithsonian Institution January 17, 1945.

their detached and distant positions in the sky defy mere man's ability to guess. Even though we have been told that the sun is almost a million miles in diameter I doubt very much that it looks that big to most of us. Certainly it did not to the American Indian. Nor did it look to him as though it were 93,000,000 miles away.

The astronomer with his optical instruments and mathematical calculations has given us the explanation of a vast universe with widely separated bodies pursuing their orderly and intricate orbits and producing a series of predictable and explainable results, which to the unaided eye are not always what they appear to be. Most of us who are laymen accept these statements on faith and dismiss the general subject of the universe on the grounds that it is all too remote to be of intimate concern to us, except for that portion of our own planet which furnishes the stage for our activities. Insofar as the sun fits into the universal scheme, we also accept academically the assurances given us that the seasons, the growth of plants, weather and other phenomena are the result of the apparent motion of the sun. The average man among the American Indians felt much the same way about it. He accepted on faith what his mentors told him and as a rule did not bother to check the information. The main difference between us lies in the details of the information we receive.

It has probably not occurred to many of us that the periodicity of the sun producing such fundamental time units as the day and the year has developed with us a time consciousness which is all out of proportion to that of most Indian tribes. It was not typical of Indians to count the passing years and no Indian unless very young knew his age in years. We must except from this general statement, however, some of the tribes of Middle America. Perhaps it would be better for us if we were not so aware of our ages. One often hears, with reference to Indians, such pat expressions as "So many winters had passed over his head," or that a man was "so many winters old." Such expressions came into being only after contact with the whites.

What the Indians of North America would say was "I was so big when such and such an event took place," such as a famine, a war, or other conspicuous happening. Among the Hupa of California, age is judged by the amount of wear on the teeth. Instead of speaking of age in terms of time units, a Hupa would say, his second teeth have just come in, his teeth are worn smooth, or his teeth are worn to the gums. This method was universally applicable since before the coming of the whites the Indians seldom lost their teeth through decay or other causes, and among California tribes, eating acorn meal leached through sand and ground in stone mortars produced conspicuous wear on the teeth.

In short, the tribes north of Mexico, because of a lack of pre-occupation with time units as marked by astronomical phenomena,

failed to develop a feeling that the passage of time was worth recording. The so-called historical calendars, annals, winter counts, notched sticks, and the like are concerned with the recording of events in a vague historical sense and are not really time reckoning. Moreover they were simply intended as memory jogs to a few individuals and were not understood by the people in general.

To some tribes, such as the Nootka of Vancouver Island, the sun evidently looked like a disk. Apparently this was true of the Aztecs and other Mexican tribes who in stone carving and metallurgy represent the sun as a disk. To other groups it appeared round like a ball, as among the Californians and some Panamanian tribes who carved representations of the sun in the form of a sphere. To others who thought of the firmament as a solid dome-shaped roof, the sun appeared to be a round hole through which the light came. A similar idea, like that held by some of the southern Californian tribes, is that a round spot was cleaned off on the sky by the finger of some mythical character, much as one might clean a spot on a dirty window pane letting the light through.

Many tribes thought of the sun as the actual person of a deity, while others thought of it as an inanimate luminous object controlled by the deity, but not being the deity itself. Therefore when the sun god is mentioned among some Indians it refers directly to the sun, while among others it refers to the deity who controls the sun. The thought of the sun as an inanimate object is not as common as the other, and curiously enough is held by the more primitive groups such as some of the California Indians, where the sun is bandied about by various mythic animals like a loose football.

The sun is probably the most universally venerated deity among the aboriginal American Indians. Nevertheless there are many tribes where the sun is considered of very minor importance. On the other hand there are many groups who regard it as their principal deity. In general the sun is most venerated among the agricultural tribes, and the more highly advanced the group, the more important does the sun become. Thus the peak of sun worship is found among the Inca, the Maya, and the Aztecs, and the sun deity partakes much more of the nature of an abstraction than is the case among the more primitive tribes.

The moon, among many Indian groups, is regarded as a powerful being, yet frequently wielding an influence that is evil or dangerous, whereas the sun is usually beneficent. In most cases the sun is masculine and the moon feminine, but this is far from being a universal concept. The Eskimo, the Cherokee, and the Yuchi, to name a few, regard the sun as the woman and the moon as the man. In the southwestern part of the United States among the Pueblo Indians and neighboring tribes, and also in southern Alaska and British Columbia,

both the sun and the moon are regarded as masculine. When the sexes differ, the sun and moon are usually considered as man and wife, and the Tlingit of the Northwest Coast explain the sun's eclipse as due to a visit of the wife to her husband. In a myth, which curiously enough is common among the Eskimo and the Cherokee and also occurs in South America, the sun and moon are brother and sister, guilty of incest.

In the Southwest and parts of the Pacific Coast of North America the sun and moon are conceived as material objects borne across the sky by carriers, and the yearly variations of the sun's path are explained by mechanical means—poles by which the sun bearer ascends to a sky bridge which he crosses and which is as broad as the ecliptic.

Though the sun is so generally regarded a great deity, he is seldom supreme, since almost invariably both the sun and moon are created beings who appear after man has already been accounted for, thus requiring the native theologian to account for a higher and more abstract being who created them.

Myths that concern the sun vary in detail not only among the different tribes, but often with individuals from the same tribe who recount them. Nevertheless these stories fall into several definite patterns, some of which are of remarkably wide distribution. In some instances even minor details are preserved in a myth which may extend to both American continents. Some of the more important of these are:

1. The almost universal North American tale of the hero or heroic brothers, usually twins, whose father is the sun.

2. The Phaethon myth, common in the Northwest, in which the mink is permitted to carry the sun disk and, as a consequence, causes a great conflagration.

3. The related legend of the creation of the sun, which, until it is properly elevated to a safe distance above the earth, overheats the world.

4. Tales of the theft of the sun, which are variants of the world-wide Promethean story of the theft of fire.

By way of illustrating the nature of these tales I will give a few which are typical of the patterns I have mentioned.

THE ORIGIN OF THE SUN AND MOON

Practically all the Californian peoples who discussed the origin of the sun and moon regarded them as something which was obtained or made only after man himself had come into existence on earth. They did not think of the sun as a primeval object, existing from the very beginning. In central California the presence of the sun was usually accounted for by a theft story, the sun being possessed by

people far off and being stolen from them for the benefit of the tribe relating the story. In southern California the sun was made usually from clay or spittle. The Californians were in no sense sun worshipers, and that luminary played a very unimportant part in their religious beliefs. Moreover, they gave very little attention to the yearly movements of the sun, and most tribes did not take special note of the time of the solstices, although these could easily enough have been determined by simple observations. By some tribes in central California, such as the Yuki, the sun was conceived of as a deity who was the patron of doctors who cured rattlesnake bites.

Of even less importance than the sun in California was the moon. The Maidu had a tale about the restriction of the movements of the two luminaries to night and day. In northwestern California there was the interesting belief that the waning of the moon was due to its being eaten by Lizard in the sky. The Luiseño thought that the first people raised the sun into the sky with a net.

Some of the California tribes believe that the souls of the dead ascend to the sky where they take up their abode and become stars. There are many different versions among the different groups as to how this final abode is reached. One tells of the soul ascending with the rising sun until the meridian was reached, thence proceeding to the milky way which was the pathway to the other world (Gifford and Block, 1930).

The Diegueño of southern California explain the sun in their creation myth:

In the beginning there was no land. There was nothing but salt water, the great primeval ocean. Under this water lived two brothers who always kept their eyes closed because of the salt water which would blind them if they opened their eyes.

After a time the oldest brother, Chaipakomat, rose to the surface of the water and looked around. He saw nothing but water. Soon the younger brother came up but on the way he opened his eyes and the salt water blinded him, so that when he did reach the surface he could see nothing and therefore returned to the deep.

The older brother decided that there should be something in the world beside water, so he first made little red ants. He made so many of them that they filled the water very thickly with their bodies. This made land.

Then Chaipakomat caused certain birds with flat bills to come into being, but because there was no sun or light these birds got lost. So Chaipakomat took three kinds of clay, red, yellow, and black, and made a round flat object. He threw this up against the sky and it stuck there. Soon it began to give a dim light. Today we call this the moon. But Chaipakomat was not satisfied, for the light was poor. So he took some more clay and made another round flat object and tossed that up against the other side of the sky. It also stuck there and sent forth a very bright light. We call this the sun. (Gifford and Block, 1930.)

In another version Chaipakomat formed the sun by spitting on his finger and rubbing a clean spot on the sky.

The Owens Valley Paiute have a story about Cottontail, the rabbit, and the sun. The sun was too hot, so Cottontail decided to try and change it. He traveled east to find the place where the sun emerged; he crossed ridge after ridge but always the sun came up beyond. Finally he reached a great sea, here he saw Sun emerge from the water, shaking himself. Cottontail grabbed Sun as it came from the water and by covering it with a slice of fresh liver, cooled it off somewhat. Now the sun is not too bright. (Steward, 1943.)

The Kato sun-theft story is as follows:

Coyote slept with his head to the east and his forehead grew very warm.

"I dreamed about the sun," he said when he awoke.

Then Coyote decided to get the sun and bring it back for the people. He set off. On the way he met three mice, and he took them with him for dogs.

"My heart is glad because I found you, my three dogs," he told them.

When they arrived at the house where Coyote knew the sun was, he instructed his dogs.

"The sun is covered with a blanket and tied down in the middle of this house. I am going in and shall sleep there tonight. When all are asleep you must come in and chew off the straps that hold the sun. Leave, however, the straps with which I am to carry the sun. When you are through, poke me with your noses."

Coyote then went into the house.

"I do not want food, grandmother," he said to the old woman of the house. "I will sleep."

"Yes," said the old woman, and gave him a blanket.

Covering his head in it, Coyote began to sing: "You sleep, you sleep, you sleep." Soon the woman fell asleep. After a while the mice came and poked Coyote.

"We have finished," one of them said.

So Coyote got up, took the sun, and carried it off. Mole saw him do this and he called out: "He is carrying off the sun," but no one heard him for his mouth was too small. Then Lizard saw him. He took up a stick and beat on the house of the old woman, calling: "He is carrying off the sun."

The old woman heard this time and she got up and started to chase Coyote.

As she neared him she called out to him: "Why did you take it? I was fixing it."

"You were hiding it," Coyote called back. "Turn into a stone where you are standing."

At these words of Coyote the woman turned into a stone. Then Coyote took the sun and cut it up, and from it he made the moon, the stars, and the sun. As he made them he told them when they were to appear.

To the morning star he said: "You shall come up just before day." To the sun he said: "You shall come up in the east in the morning, and go down at night. You shall be hot." To the moon he said: "You shall travel at night. You shall be cold."

The people were very grateful to Coyote for what he had done and they brought him many presents upon his return. (Gifford and Black, 1930.)

According to the Pomo, formerly the sun did not shine and everything was dark.

When the people went hunting or traveled they had to carry torches for light. People were much disturbed because they could not tell which end of the day was night and which was day.

Lizard once went hunting with his torch far to the east, until one time he saw a little light. He reported this to the people but was not believed. Various animals were sent to investigate but all failed, until the Dove returned and reported finding a village far to the east where the sun was kept and it was daylight all the time. An expedition was sent to steal the sun. After many difficulties they succeeded in releasing the sun from the sack in which it was sewed.

The people then started to roll the sun along toward their village but the Sun-people pursued and fought with them, with the result that arrows were shot in all directions and fell everywhere. That is the reason why you can find arrowheads scattered all over the country now. They all came from this war.

When they had taken the sun about halfway home, they tried to put it up in the sky. All of the different kinds of birds tried this. Dove tried first, then others. Finally, the Crow brothers succeeded in hanging it up and it stayed there. The Crows were able to hang the sun up in the sky, because they were able to go without water for a longer time than any of the other birds. (Barrett, 1933.)

This story of the sun is told by the Achomawi.

One time Sun conceived the great idea of rolling along on the ground instead of in the sky. So she fell down from the sky just about sunrise.

But Mole saw what Sun was trying to do and he ran and caught hold of her. He held her up as high as he could, while he shouted in a loud voice for the people to come and help him.

All the people came running when they heard Mole's excited voice. With much shoving and pushing they helped Mole shove Sun up into the sky again. Otherwise today we would not have Sun in the sky, but instead she would be rolling along on the ground. It was from holding up Sun that Mole's hands are bent so far back.

The Maidu say that

a long time ago, in the days before Indians lived on this earth, a brother and sister lived together far away to the east. They were Sun and Moon. Instead of rising every day and traveling over the world as the people wanted them to do, they remained within their house, which was made of solid stone. Many people were sent to try and see if they could make the two rise but all failed for they could not even enter the house built of solid stone. At last Gopher and Anglemorm went.

When they arrived at Sun and Moon's stone house they stopped to consider how best to enter. Anglemorm made a hole in the ground, boring down outside and coming up inside the house. Gopher followed, carrying a bag of fleas. Once inside, Gopher opened his bag and let half of the fleas out. The fleas began to bite Sun and Moon, making them move around. Then Gopher let out the rest of the fleas. These made life so miserable for Sun and Moon that they decided to leave the house.

Sun said to her brother: "Both of us cannot travel together. Do you wish to travel by day or by night?"

Moon replied, "You try traveling by night."

So Sun tried it; but the Stars all fell in love with her, and she could not travel because of their attractions. Sun then went back and told her brother that he must go by night. This he agreed to, and has done ever since. Sun traveled by herself in the day. (Gifford and Block, 1930.)

Many Northwest coast tribes have their versions of the theft of the sun. Among the Kwakiutl it was said that

at first all was darkness and living was very difficult and uncomfortable for the people. This was because a certain chief who lived in a cave had the sun and the moon in a box which he kept tightly closed in his cave under a great mountain.

The people tried in many ways to get the box but all efforts failed until Raven through trickery changed himself into a small leaf in a spring where he had observed the chief's daughter came regularly for water. She dipped up Raven and swallowed him when she took a drink. Raven then turned into an infant and was given birth by the girl in her father's cave. Raven turned out to be a very fretful and disagreeable child constantly crying for the box which contained the sun and moon. At last the exasperated chief gave it to him to play with and he at once quieted down and became very cheerful. Of course when the chief fell asleep, Raven ran off with the box. He was pursued but escaped. When he returned with the box containing the sun, the people called him a liar, but he opened the lid a little and everyone was dazzled by the brightness and urged him to tone it down. So Raven placed the sun in the sky where it is bright enough to light the world but not too bright. The moon was also hung in the sky to light up the night.

The place of sunrise, according to the Bella Coola, is guarded by the Bear of Heaven, a fierce warrior, inspirer of martial zeal in man; and the place of sunset is marked by an enormous pillar which supports the sky. The trail of the sun is a bridge as wide as the distance between the winter and summer solstices; in summer he walks on the right-hand side of the bridge, in winter on the left; the solstices are "Where the sun sits down." Three guardians accompany the sun on his course, dancing about him; but sometimes he drops his torch, and then an eclipse occurs.

Not many Pacific coast tribes have as definite a conception of the sun as this, and, generally speaking, the orb of day is of less importance in the myths of the northern than in those of the southern stocks of the Northwest. It is conceived both as a living being, which can even be slain, and as a material object—a torch or a mask—carried by a Sun Bearer. One of the most widespread of Northwestern legends is a Phaethon-like story of the Mink, son of the Sun, and his adventures with his father's burden, the sun disk.

A woman becomes pregnant from sitting in the Sun's rays; she gives birth to a boy, who grows with marvelous rapidity, and who, even before he can talk, indicates to his mother that he wants a bow and arrows; other children taunt him with having no father, but when his mother tells him that the sun is his parent, he shoots his arrows into the sky until they form a ladder whereby he climbs to the Sun's house; the father requests the boy to relieve him of the sun burden, and the boy, carelessly impatient, sweeps away the clouds and approaches the earth, which becomes too hot—the ocean boils, the stones split, and all life is threatened, whereupon the Sun Father casts his offspring back to earth condemning him to take the form of the Mink.

In some versions the heating of the world results in such a conflagration that those animal beings who escape it by betaking themselves to the sea are transformed into the men who thereafter people the earth.

The Huron of the Great Lakes area thought that the earth was pierced and that when the sun went down it entered this hole and remained hidden until the next morning when it came out at the other end.

Eclipses were interpreted as good or bad auguries depending on the place in the sky at which they happened to be. One darkening of the sun was supposed to have happened because the Great Turtle, which holds up the earth, in changing its position brought its shell before the sun and thus cut off the light.

Among the Mohawk and some of the Huron, eclipses were believed to be due to the Great Frog Monster swallowing the sun. Under such circumstances the Indians had to organize impromptu ceremonies and by dint of the beating of drums, howling, and in general making as much noise as possible, force the frog to disgorge. Thus far these methods have always been successful.

The Huron also believed that if an individual failed to perform the winter rites required of him through dreams, the sun would be held back, i. e., the coming of spring would be delayed.

The Canadian Iroquois had a legend that when the sun should make his daily rounds for the benefit of man it was also decided that the sun of the daylight should rule the earth.

In addition, it was resolved that times should change; that there should be winter months and summer months, thirteen in all, and each should be given a name.

"There is a tree, composed of the languages of the nations of the earth, standing where the sun emerges.

"When the sun flies along where the tree stands he dances, saying, 'I will take care of the people living towards the West.' Then he climbs the sky. When in the middle of the sky he stops for awhile to rest and repeats what he said on emergence and continues dancing.

"In the evening at sunset, he says 'I am glad to have done my duty' and sinks below the ground."

The idea of the sun standing still for awhile at the zenith is found among many tribes from coast to coast.

In ceremonies among the Iroquois, the moon is always addressed as "our grandmother" and the sun as "our elder brother."

The Algonquians have a series of myths in which various deities engage in a celestial ball game. The Golden Eagle is the leader of the benign gods and the Bear the leader of the underground people. The Eagle always wins. This game symbolizes the eternal conflict between day and night, the ball itself being the sun. The day is the perpetual conqueror.

There is also a story of the Menominee in which Tchakabech, a kind of Indian Jack-and-the-Beanstalk, climbs to heaven on a vine and snares the sun in a net. During its captivity there was no day on earth, until a mouse cut the strands of the net with his teeth, releasing the sun and restoring the day.

Among many of the Pueblo tribes of Arizona and New Mexico, the sun is very important. Typically, when the first people emerge from the underworld they find the world is dark. This is very inconvenient so a culture hero or the war twins are sent out to look for the sun and, having found it, to place it properly in the sky and plot its path. The Pueblo Indians believe that at the winter and the summer solstices the sun remains motionless for 4 days each, during which time he rests in one of the two houses that exist for this purpose at each end of his path. It is also believed that for a short time at mid-day the sun stands still in its path across the heavens. In myth this is explained when his course across the sky is interrupted when he permits his twin sons to carry his shield.

In Hopi myth, Sun had to be helped to move on across the sky by killing a child, and his transit is still dependent on someone's dying every day at morning, noon, and evening. Sun has two houses for daily use. In the morning he "comes out standing to his sacred place." In the evening, he "goes in to sit down at his other sacred place." The farthest point on the horizon that he reaches at sunrise or sunset, the northernmost point in summer, the southernmost point in winter, is the "house" where he remains 4 days before turning back to winter or to summer.

In no Pueblo myth except at Oraibi is Sun described as a creator.

The Hopi hold special ceremonies on observing the solstices for the purpose of slowing up the sun on its way toward winter, and hastening it on its way toward spring.

Eclipses are viewed with fear as portents of evil. One year there was a lunar eclipse on the eve of the day the school children at Santa Fe were to return to Taos. The Governor of Taos telegraphed the school authorities to postpone the children's journey, and it was postponed for a week. (Parsons, 1939.)

The Natchez were one of the civilized tribes of the lower Mississippi Valley for whom, fortunately, we have rather complete data before the native culture broke down under the impact of European civilization. They were mound builders and their beliefs and customs resembled more closely those of Mexico than any other group north of the Rio Grande, and probably resembled the beliefs of the former occupants of the great mound groups of the southeastern area generally.

The Natchez believed the universe to be filled with spirits in human forms who differed in power, the most powerful of all being a sky deity who lived in, or was connected with, the sun. Here we find ourselves a step in advance of the usual northern concepts regarding the sun.

The Sun clan was considered to be descended from this sky deity and hence had a divine right to the unusual honors and regard lavished

upon it, while, as head of the Sun people, the great chief was the representative of the deity on earth and was to be treated accordingly.

In other words, the Natchez state was a theocracy. The Supreme Being resided in the Sun. The son or near relative of the Supreme Being, having come to earth, taught men religious customs, established the government, then retired into a stone which continued to dwell with the people in the innermost sanctuary of the temple, and his descendants ruled in his place. The great chief, supreme ruler of the Natchez, lived in the temple and was revered as a demi-god.

Charlevoix, who lived among the Natchez, gives us this description :

Every morning as soon as the Sun appears, the great chief comes to the door of his cabin, turns himself to the east, and howls three times, bowing down to the earth. Then they bring him a calumet, which serves only for this purpose. He smokes, and blows the smoke of his tobacco toward the Sun; then he does the same thing toward the other three parts of his world. He acknowledges no superior but the Sun, from which he pretends to derive his origin. He exercises an unlimited power over his subjects, can dispose of their goods and lives, and for whatever labors he requires of them they can not demand any recompense.

Le Petit gives us a similar account.

The sun is the principal object of veneration to these people; as they cannot conceive of anything which can be above this heavenly body, nothing else appears to them more worthy of their homage. It is for the same reason that the great chief of this nation, who knows nothing on the earth more dignified than himself, takes the title of Brother of the Sun, and the credulity of the people maintains him in the despotic authority which he claims. To enable them better to converse together they raise a mound of artificial soil on which they build his cabin, which is of the same construction as the temple. The door fronts the east, and every morning the great chief honors by his presence the rising of his elder brother, and salutes him with many howlings as soon as he appears above the horizon. Then he gives orders that they shall light his calumet; he makes him an offering of the first three puffs which he draws; afterwards raising his hand above his head and turning from the east to the west, he shows him the direction which he must take in his course.

Next to the sacred stone, the holiest object in the temple was the eternal fire, which was supposed to be derived directly from the sun. The tender of this fire had one of the most responsible duties in the nation since, if it were allowed to go out, the very nation itself would be extinguished. (Swanton, 1911.)

The Southeastern tribes in general had similar ideas of the sun and of the relationship between the sun and fire. Adair, an early traveler among the Creeks, records an interesting episode that he witnessed at a Creek ceremony. A Creek having become intoxicated, reeled into the fire and roared, foamed, and spoke the worst things against the sun that their language could express. He upbraided him with ingratitude for having treated him so barbarously in return for his religious offerings, affirming he had always sacrificed to him the first young buck he had killed in the New Year; he had always offered him when

at home some of the fattest meat, even when he was on short allowance, on purpose that he might shine on him kindly. "And," he added, "now you have proved to be like an evil spirit, by biting me who was your constant devotee, and are kind to those accursed nothings (the white people) who are laughing at you as a rogue and at me as a fool, I assure you that I shall renounce you from now on, and instead of giving you fat meat you shall get water. I am a respected warrior and as such I scorn to lie—you shall therefore immediately fly above the clouds."

The psychology here is all aboriginal and fits in with the Natchez belief as described. The connection between the ceremonial fire and the solar fire is apparent.

Since our American Indians are of remote Asiatic origin, it is interesting to note that many of these ideas of the sun are still to be found in Asia. For example, the ancient religion of Japan is known as Shinto or "the way of the Gods." It is essentially a worship of nature gods, especially the sun, and not of ancestors as has sometimes been erroneously stated.

This ancient worship of nature gods was long thrust into the background by Buddhism, the moral teachings of which contrast with the absence of ethical teaching in Shinto.

However, since Japan recently started her campaign of conquest there has been a general return to Shintoism as better suited to a militaristic people. It is interesting to read what Sir James Frazer wrote more than 20 years ago:

The old faith still retains a certain hold on the mind of the people, manifesting itself particularly in that adoration of the Sun which appears to have been from the earliest times a salient feature of the national religion. The absence of a moral code in Shinto is acknowledged by modern native commentators, who account for it by the innate perfection of the Japanese nature, which renders such outward props of morality superfluous. It is only, they insinuate, the inferior races, such as the Chinese and Europeans, whose natural depravity requires from time to time to be corrected by the preaching of sages and reformers.

Of all the Shinto deities (kamis), the most eminent is the Sun Goddess, the personification of the physical sun. She is described as the Ruler of Heaven and as unrivaled in dignity. She wears royal insignia, is surrounded by ministers, and is spoken of in terms appropriate to personages of sovereign rank. From her the Mikados claim to derive their descent and authority. Yet she is hardly what we understand by a Supreme Being. Her power does not extend to the sea and to the Land of Darkness (yomi), the Japanese Hades. The commission to rule the Heaven was conferred on her by her parents, and did not by any means convey despotic power. Important celestial matters are determined, not by her, but by a Council of the Gods. The heavenly constitution, like its earthly counterpart, on which no doubt it was modeled, is far from being an absolute monarchy.

The ordinary Japanese name of the Sun Goddess is Ama-terasu no Oho-kami, "the Heaven-shining Great Deity".

Partly under cover of a name which is less intelligible to the multitude, the tendency has increased to throw the solar nature of the goddess into the shade and to conceive of her simply as a general Providence at the expense of other divinities. In this way she has made a distinct advance to the dignity of a supreme monotheistic deity. (Frazer, 1926.)

We find, therefore, among the American Indians, that the tribes of simple hunting, fishing, and seed-gathering cultures regard the sun as of distinctly minor importance. In some instances the sun is looked upon as an inanimate object, the pawn of various minor deities. In other cases, usually in tribes of slightly higher culture, the sun is personified as a male or female being whose presence and activity is accounted for in myth, and is usually linked with the moon. Seasonal phenomena are but loosely connected with the sun and calendrical ideas are crude and very limited.

Among the more advanced nonagricultural people, such as the tribes of the Northwest Coast and the Eskimo, concepts of the sun are similar, but astronomical observations are made, the solstices are observed, and the calendar is more developed and systematic.

The Pueblo tribes of the Southwest States, a well-advanced agricultural group, represent the next stage. Here the sun becomes very important but is still secondary to a few other deities such as the Corn Goddess. Signs may be seen, however, of the beginnings of a higher conception of the sun as a sky god with such customs as the presentation of newborn children to the rising sun. Astronomical observations are rather advanced. Much significance is attached to the solstices and the seasons, and the connection of the sun with life and growth is well recognized.

The Natchez, probably reflecting Mexican ideologies, regard the Sun God as the Supreme Being, but with many lesser deities also recognized, the visible sun being the residence of the personified Sun Deity. The Sun Priest, human representative of the Sun on earth, is a lineal descendent of the Sun and as such is treated as a deity. The eternal fire symbolizes the Sun and man's dependence on it for life.

The high civilizations of Middle America are typified by the Aztecs and the Incas. Here again the sun is the Supreme God, but the abstract concept of the god is not so much confused with the visible sun, which is regarded more as a symbol than a godhead. Thus, a typical Inca prayer to Huiracocha, the Sun God, says "Oh Huiracocha, whatever form thou hast, wherever thou might be!"

The Aztecs had a similar abstract idea of the Sun God.

The Aztecs and their neighbors developed, along with the increasing importance of the sun, an elaborate calendar system. Among the Maya this achieved a greater perfection than it had in Europe at the time of the discovery of America. This calendar was used by the priests

to select lucky and unlucky days, and their astronomical observations were so accurate that they were able to foretell eclipses. Among all these tribes there was a tendency to transfer the attributes of other nature gods to the sun as the Sun God grew in importance.

However, it is interesting to note that as between the Aztecs and the Inca, ritualistic attitudes toward the sun differed widely. In each instance we have a picture of polytheism in the process of turning into monotheism through increased recognition of the vital role played by the sun in the life and affairs of man.

The next stage in this process is where the astronomical sun is more or less completely divorced from the god which developed from the sun, to become a supreme god of life, culminating in the recent stages of civilization where the mechanistic or astronomical concept of the universe supplies the explanation of the heavenly bodies, and the god idea is completely separated from immediate connection with them.

In one sense this completes a curious cycle, since otherwise it is only among the most primitive tribes that we find the sun regarded as an inanimate object.

Among the American Indians this cycle was never completed, but reached its greatest advance among the Middle American agricultural civilizations.

The range of ideas concerning the sun varied from the naive idea that it was a ball of fire, convenient, but not essential, to man, to the elaborate astronomical concepts of the Maya, who, while they did not understand the true nature of the universe, nevertheless observed so accurately the movements of the heavenly bodies that they had worked out the periods of the sun, the moon, and the planets more accurately than any other people in the world up to their time.

It would be interesting, though futile, to speculate on what their achievements might have been had not European civilization intervened.

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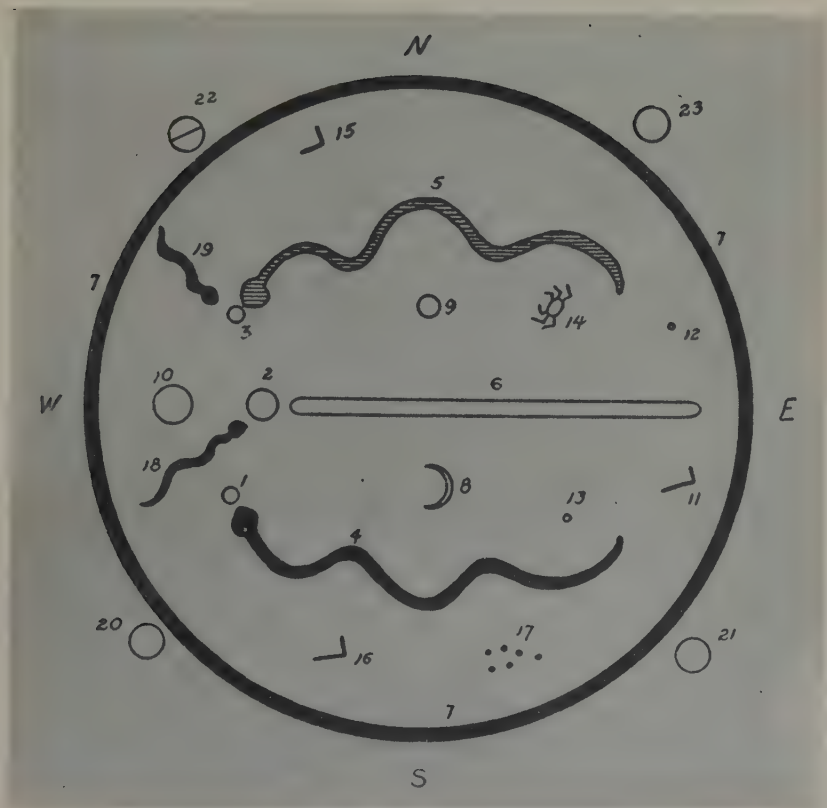
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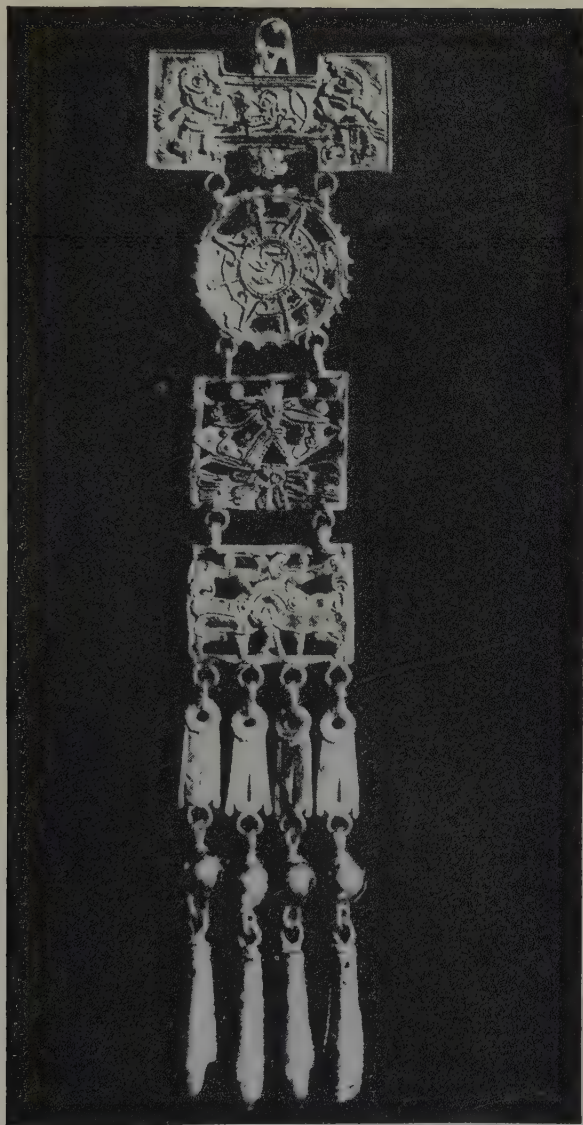


DIEGUENO GROUND PAINTING REPRESENTING THE UNIVERSE.

The sun (10), new moon (8), full moon (9), Milky Way (6), world's edge (7), Pleiades (17), etc. (After Gifford and Block.)

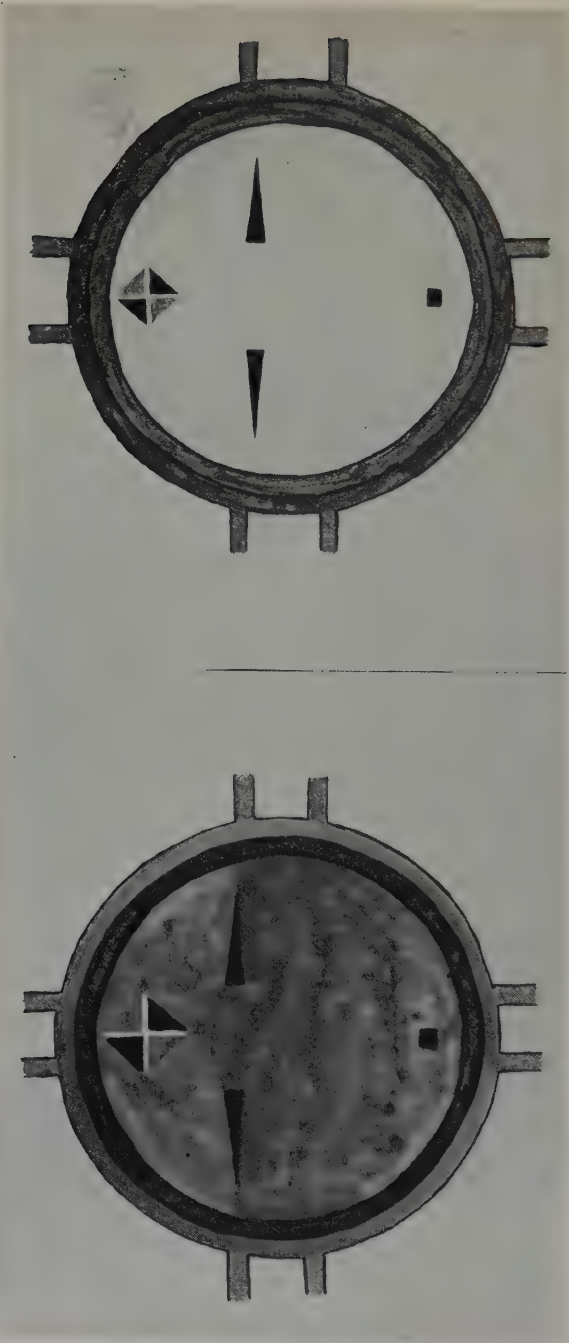


AZTEC SACRIFICE TO THE SUN, FROM THE CODEX FLORENTINO.
(After Vaillant.)



MIXTEC GOLD ORNAMENT REPRESENTING THE VERTICAL UNIVERSE.

Top, ball court symbolizing the sky; next, the sun disk; then the moon; and at the bottom, the earth monster.



ACOMA PAINTINGS OF THE SUN AND MOON.

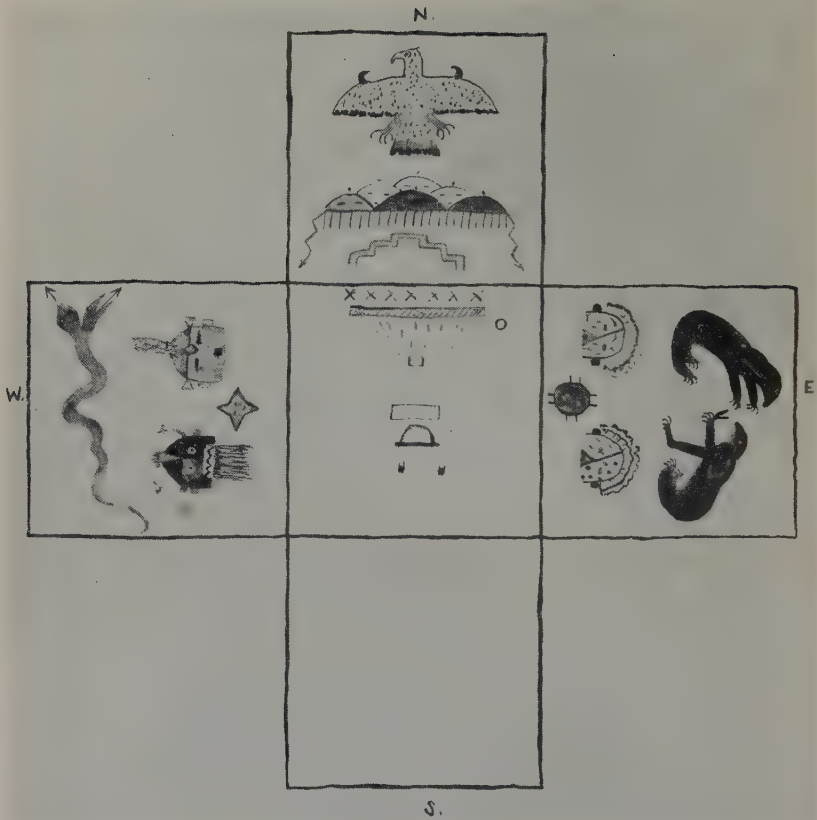
The sun is male and painted red; the moon is female and painted yellow.



ACOMA SAND-PAINTING ALTARS.

Upper, the universe. The rim is painted blue and represents the sky; the upper crescent contains the sun, moon, and stars; the arc is the Milky Way; the bird figure is the Earth Goddess.

Lower, Ant Society altar with symbols of the sun, moon, and stars.



THE UNIVERSE AS REPRESENTED BY THE FLOOR AND FOUR WALLS OF AN ACOMA KIVA.

The floor (in center) is the earth and the four walls are the four quarters of the sky.

HUMAN PROBLEMS IN MILITARY AVIATION¹

By DETLEV W. BRONK

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One of the memorable experiences of this war is to stand at evening in the great court of Trinity College, Cambridge, outside Isaac Newton's rooms, and watch the flying forts return. Against the soft English sky they move in stately formation, seeming to proceed slowly because of their great height. Their silhouettes, floating by the hundreds through the wisps of clouds, move one with admiration for man's mechanical genius that has driven his machines into the skies, against the force of gravity.

A little later, in the gathering dusk the fortresses roar down the runways of their scattered fields, and the machines are revealed as mere instruments of human crews. Waist gunners sit casually in their openings, waving as they pass; bombardiers are in their transparent cages; pilots taxi their ships to rest. They are men returning from a mission made doubly hazardous by enemy action and the dangers of an environment unnatural to man. These are the crews who make the majestic armadas of the air a symbol of man's new freedom from natural limitations, gained by courage and by science.

The history of aviation is a long record of man's restless urge to exceed the physiological restrictions of his body. It first appears in mythology and ancient literature as a desire for the birds' freedom from the gravitational tie to earth. Yet, when in 1783 man was at last freed from his earth-bound life, he was but started on the conquest of his limitations. Each new power provided by the physical sciences has placed new stresses on the human body and has carried man into environments to which he has not been adapted by the slow process of evolution.

The first of these limiting conditions appeared soon after the pioneer balloon ascent. For by 1803 the science of aeronautics had so far pro-

¹ Read April 20, 1944, in the Symposium on Wartime Advances in Medicine. Reprinted by permission from *Proceedings of the American Philosophical Society*, vol. 88, No. 3, September 1944.

gressed that Robertson, the French physicist, succeeded in reaching an altitude of 22,000 feet, where he experienced an overpowering sense of indifference. "There," said he, "the scientist is no longer sensitive to the glory and passion of discoveries, and it is only by the aid of a little fortifying wine that he succeeds in finding intervals of mental clarity and power."

Driven by the urge for greater range of action, man's ingenuity devised means for ascent to ever higher altitudes, until in 1862 Glaisher, the English meteorologist, and Coxwell, his ballon engineer, reached the limits of human survival. They went to a reported altitude of 29,000 feet, but Glaisher was unconscious, and both would have perished had not Coxwell, paralyzed though he was, seized the valve cord in his teeth and released the gas by vigorously nodding his head. On recovering consciousness, Glaisher voiced man's faith in the power of science to break the bounds of human limitations: "I certainly shall not take it upon myself," said he, "to set the limits of human activity and indicate the point, if it exists, where nature tells the aeronaut: 'You shall go no further.'"

His confidence was soon justified, for it was but a few years later that Paul Bert, the physiologist, discovered the cause of man's failure at high altitudes and prescribed the means for overcoming this restriction on human flight. Two causes were suspected: the reduced barometric pressure and the lower volume concentration of oxygen in the atmosphere. Both of these factors are now known to be a hazard to the airman, but the cerebral symptoms then described were shown by Bert to be the consequence of too little oxygen in the inspired air. This he proved by placing a man in a large metal chamber, in which he could be subjected to one or the other of the two conditions.

From that time on, the vital dependence of the brain upon an adequate and continuous supply of oxygen has been well recognized. The recent development by my colleagues—Davies and Brink—of an electrochemical method for measuring the concentration of oxygen among the nerve cells of the intact cerebral cortex emphasizes this essential need. By exact measurements, it is now possible to gain a clearer understanding of the brain's requirement for oxygen and the factors which regulate the supply of this essential element. Pertinent to this discussion is our observation that as the recording electrode is moved to points on the cortex farther and farther from a blood vessel, the concentration of available oxygen decreases steeply until, at a point 25–50 microns from a vessel, the concentration may be less than a tenth of that in the arterial blood. This steep gradient of concentration insures effective diffusion of oxygen to the cells, but their avid consumption keeps the reserve supply at a low level. In consequence of this, a deficiency of oxygen in the blood is quickly followed by a

precipitate drop in the oxygen surrounding the cells. Rapid failure of nervous function then ensues.

To protect the cells of the brain against this danger, the human organism possesses a remarkable system of reflexes. When the oxygen concentration in the blood flowing to the brain declines, certain nerve cells are stimulated to action, and that action causes an increase in the rate and depth of respiration. Thus more oxygen is again supplied to the blood flowing through the lungs. The heart rate is also accelerated, and more blood is sent to the brain in order to maintain the necessary diffusion of oxygen out to the nerve cells.

Even in the early days of flight, such a sequence of events was observed to be a natural protection of an airman against one of the dangers of high altitude. For in 1804 Gay-Lussac reported that his heart rate and respiration were progressively increased during the course of a balloon ascent. But as the aeronauts ascended to higher altitudes, where the oxygen was less plentiful, the physiological protective mechanisms were ultimately inadequate. To supplement these natural powers of adaptation, it was, accordingly, necessary to provide some means for increasing the oxygen delivered to the lungs. To do this, Paul Bert simply provided small containers of oxygen, with tubes which could be inserted in the mouth.

For 50 years this simple expedient satisfied the needs of airmen, excepting the few who went to unusual heights. But now the strategy and tactics of aerial war make operations above 30,000 feet a routine event, and new problems have arisen. At those altitudes, the oxygen in the atmosphere is so low that care must be taken to seal the nose and mouth against the outside air, lest the oxygen drawn from the reservoirs be too much diluted. To accomplish this, facial masks have been designed which open to the air through a valve only during expiration. It is thus possible to deliver pure oxygen to the flyer.

If this be done for the 10-man crew of a bomber on a 6-hour mission, hundreds of pounds of oxygen tanks are required. This, in turn, reduces the gasoline and bomb load by a corresponding amount, and the airmen, although physiologically protected, accomplish less on their military mission. To make the most effective compromise between human necessity and strategic efficiency, it is, accordingly, desirable to supply just enough oxygen to satisfy the requirements of each individual under any condition of altitude or bodily activity—just that and no more.

The natural indicators of what this need is at any moment are the nerve cells of the respiratory centers, which regulate the rate and depth of respiration. Their action can, in turn, be made to control the flow of oxygen to the aviator's mask, by placing in the supply line a regulating valve which is activated by the suction created by each

inspiration. To gain further economy, oxygen from the tanks is mixed with outside air so as to utilize the oxygen available in the atmosphere. In order that this dilution be not too great at the higher altitudes, the mixing occurs through an aneroid-controlled valve. It will be obvious that the safe and economical design of such equipment depends upon precise physiological knowledge concerning the rate of oxygen supply required by the human organism, the individual variations in this requirement, the additional oxygen needed at any altitude, the tolerable inspiratory and expiratory pressures and the effects of varying degrees of work on the respiratory demands. Our modern oxygen supply systems are, accordingly, the products of close cooperation between the physiologist and the engineer. With this equipment, men now go safely to 38,000 feet.

There new limitations appear, for the barometric pressure at those altitudes is so low that insufficient oxygen goes into the blood passing through the lungs, even though pure oxygen be delivered to the mask. Unless this situation is overcome, new aircraft designs and engine superchargers are not usable in outreaching the range of enemy anti-aircraft fire. To satisfy the human requirements at these great heights, oxygen must be delivered under a pressure sufficiently high to load the blood adequately.

Two methods are now available for accomplishing this. One is to design the oxygen regulator, valves, and mask so that a pressure can be maintained greater than that of the ambient air. The other is to seal the aircraft cabin and keep the interior at sufficient pressure by means of a mechanical compressor. The first is a temporary expedient. The latter is an ideal solution, for it gives the crew adequate oxygen with complete freedom of movement, unencumbered by mask and tubes leading to a reservoir. The sealed aircraft enclosure has the further considerable advantage of providing warm surroundings for men who must quickly go from a temperate or tropic climate to regions where the temperature is 40° F. below zero. With such pressurized cabins the engineers have at last restored to fliers their natural environment, while taking them to altitudes unsuitable for life.

One of the most dangerous hazards of high-altitude flight is the insidious character of the symptoms of beginning oxygen want. As the early balloonists described them, they are lack of mental clarity or even a sense of well-being that masks the danger of imminent catastrophe. It is, therefore, not feasible to rely upon the judgment of an airman as to when he is in need of his supplementary oxygen supply, unless he be thoroughly familiar with his physiological requirements and the means for satisfying those demands.

In order to forestall such dangers, the Army Air Forces and the Navy have during this war instituted altitude training programs for instruct-

ing every pilot and air crewman in the basic physiological principles that relate to life at high altitudes. In the Army, 60 modern replicas of Paul Bert's "altitude chamber" have been erected at 45 airfields. Under the direction of some 200 aviation physiologists, student fliers in groups of 10 or 20 are placed in these chambers for several hours, while the atmosphere is made to resemble that which they will later find at 35,000 or 40,000 feet. Under careful supervision, they experience the effects of inadequate oxygen and are taught to use the equipment available in combat aircraft for providing the additional oxygen they will require. Finally, the "chamber flights" are supplemented with lectures which give the physiological basis for the practical demonstrations. Forty-five thousand men a month have been given such instruction, in what is probably the largest medical training program ever developed to overcome an occupational hazard. This is an essential part of the training that fits the crews to fly the great bombing missions over the Nazi's European fortress.

The problems I have thus far discussed differ only in degree from those encountered 50 years ago in slow-moving balloons. The high speed which gives to modern aircraft a unique tactical advantage now confronts the flight surgeon with quite new problems. For the air crews not only ascend into an unnatural environment, but they do so with terrific speed. Climbing at a rate of 80 feet a second, an airman in 6 minutes reaches an altitude of 6 miles, where the barometric pressure is but one-third that at sea level. This sudden change in the pressure acting on the body unbalances the equilibrium of gas pressures within its cavities and tissues. The painful inward pressure on the ear drum when the eustachian tube cannot be opened is a familiar experience of all who have flown. But only the military aviator going quickly to 30,000 or 40,000 feet knows the excruciating pain caused by the sudden liberation of gases from solution in the blood or other body fluids.

It has recently been shown that during these sudden changes of pressure minute gas nuclei on the surface of cells or on the inner walls of blood vessels rapidly expand in size, growing with the nitrogen, carbon dioxide, and oxygen that is liberated from the surrounding fluid as it is decompressed. As bubbles of gas are thus formed and grow, some lodge in small terminal vessels where they obstruct the flow of blood. Nerve endings may thus be deprived of oxygen and pain results. Or regions of the brain are likewise put out of action, with widespread and serious consequences.

I must hasten to add that this widely accepted explanation of the cause of the pain of decompression sickness is not conclusively established. The theory has, however, served a useful purpose, for it has led to a practical and fairly reliable method of prevention. Assum-

ing that the bubbles are largely composed of nitrogen—that being the most plentiful source of gas within the body fluids—it was suggested that the supply of nitrogen for bubble formation could be reduced by breathing pure oxygen for some time before a flight. Nitrogen in the tissues is thus replaced by oxygen. Because the oxygen is consumed by cellular metabolism, and because its tension in the blood rapidly falls when a little is removed, it is less potent as a source of bubbles. This has been proved experimentally, and the practice of breathing oxygen before a flight or on the climb to altitude is now a proved means for preventing decompression pains.

Ultimately these symptoms will be unknown, for, in the sealed-cabin aircraft of the future, compressors will maintain the pressure constant throughout a flight to any altitude. In the meantime, engineering science has given fliers machines which overtax their physiological powers of adjustment. To make possible the tactical employment of these aircraft in long-time, extremely high-altitude photographic reconnaissance or in rapid-climb bombing flights, the discovery of the preoxygenation procedure has been a great boon.

There is another notable instance in which the accomplishments of the engineers have exceeded the capabilities of the flier. Two of the primary requirements for good fighter craft are high speed and great maneuverability. These are the characteristics which enable them to excel in plane-to-plane combat, to evade the heavier fire-power of larger craft, and to give effective protection to our bomber missions. Engineers and metallurgists worked for years to develop these planes that would withstand the centrifugal forces of high-speed turns, but during that time there were no corresponding improvements in the physiological mechanisms of the men who were to utilize these new machines.

A normal heart and circulation will deliver enough blood to the brain when the body is erect or recumbent, and will meet the needs during sudden changes in posture. Nerve messages, from pressure-sensitive nerve endings in the walls of the carotid artery and in the arch of the aorta, promptly report to the nerve centers regulating the heart and blood vessels a drop in blood pressure in the vessels supplying the brain. The effect of this is an accelerated heart rate and a constriction of peripheral vessels. Thus the circulation of the brain is again increased. But the cardiovascular system and this reflex control were not evolved for pumping blood made five to ten times as heavy by a suddenly applied centrifugal force.

Under these conditions, blood accumulates in the lower extremities and in the viscera. The result is an inadequate supply of oxygen to the nerve cells in the brain. "Gray-out," then "black-out," of vision are the first effects. If the centrifugal force be sufficiently great, and

prolonged for some seconds, loss of consciousness will follow. In less severe maneuvers there may be no obvious symptoms, but the often-repeated reduction of cerebral blood flow causes fatigue, irritability, and inefficiency. To help the human body meet these stresses imposed by the swift combat planes, belts and suits have been devised which aid the heart, by preventing the pooling of blood in the lower parts of the body. Without such devices the plane is but a futile object, unsuitable for use. A pilot may execute maneuvers that cause repeated black-out with no evidence of permanent damage, but he is a relatively ineffective fighter under those circumstances.

Aircraft maneuvers which are quite inadequate to produce such cerebral effects exert forces on the human body which make unreliable the normal sensory mechanisms concerned with posture and position. The force which holds the plane in a banked turn, or in a loop, also acts upon the gravity receptors, the tension receptors in the muscles and the tendons, and the sensory mechanisms in the semicircular canals which detect rotation. These sensory pathways are then stimulated by the resultant of this machine-exerted force and that of the earth's gravitational field. Because the sensory mechanism is unable to resolve these two components of the stimulating force, a true sense of orientation in space is lost. The false sense of position must then be corrected by visual reference to the earth. And so, when clouds or darkness interfere, the pilot becomes incapable of maintaining a desired course relative to the surface of the earth. "The night is come; be then the night obeyed" was accordingly the rule of aerial combat in the First World War, as it was for the foot-soldier in the Homeric battle between Hector and Ajax.

Finally, however, the causes of man's inaptitude for directed flight without visual contact with the earth were recognized. It was then possible to devise instrumental aids to the senses, and flight through clouds and darkness became safe and commonplace. Once again the physiological characteristics of the flier had limited his full utilization of the aircraft; once again medical scientists defined the need, and physicists provided instruments such as the artificial horizon, the bank-and-turn indicator, and the gyroscopic compass to supplement the senses. And so, the scope of human flight was once again increased. But, as we shall see, still more human problems were thus created.

The development of instruments that make possible flight by night has greatly extended the tactics and strategy of aerial war, for it enables the airman to utilize nature's most effective form of camouflage. Unfortunately, this advantage is also available to the enemy, and this, then, requires a keen ability to see through darkness the dim form of an enemy aircraft. Physicists are already at work extending the range of night vision through radar, but in the meantime men fly and fight with the aid of their natural vision.

To watch a night mission return to blacked-out Britain or to see hundreds of gliders sweeping into unlit cornfields during an airborne maneuver, is to appreciate how unnatural such duties are to the boy who has grown up with an electric-light switch at his finger tip and a flashlight in his pocket. Even the flight surgeon has had to recall forgotten facts concerning the mechanism of night vision: the fact that the cone cells of the retina, which are used in day vision, do not respond to dim lights; that the rod cells, which are used in night vision, are located in the peripheral regions of the retina, so that one sees a dim object best by looking a little away from it; that the sensitivity of the rods is destroyed for some time by a bright light, and is least affected by red of all the colors. The translation of these principles into tactical practice is an important element in the success of night operations.

A first step toward this end was a revision of lighting practice on airfields and in aircraft. Dark adaptation following prolonged exposure to bright light requires about half an hour, and until then night vision is below normal. Accordingly, a pilot who goes quickly from a lighted room into combat is relatively blind and under a severe handicap. He is likewise at a disadvantage on looking from his lighted instrument panel out into the darkness where enemy planes are hidden. To protect the airmen against these hazards, the Air Surgeon has recommended that lights to which the fliers are exposed shall be red in color, whenever that is possible. As has been said, this makes possible cone vision without affecting the subsequent sensitivity of rod night vision.

A more far-reaching effort to improve human efficiency in night combat is the establishment of a night visual training program. Following the pattern of the altitude training program, the Army Air Forces have developed a course of instruction which will familiarize the airmen with basic physiological principles relating to night vision; will warn him of the harmful visual effects of unnecessary light, of diets inadequate in vitamin A, and of insufficient oxygen. To this is added several hours of directed practice in the detection and identification of faintly illuminated objects. We have reason to believe that it is thus possible to improve visual performance in night operations by as much as 30 to 40 percent.

Just prior to our entrance into the war the National Research Council sponsored a survey of the sensitivity of rod vision in a group of several thousand military personnel. The results confirmed Hecht's laboratory findings that, within a normal population, some individuals are 15 times better fitted by their retinal characteristics for night observation than the poorest, and 5 to 10 times better than the average.

It is, accordingly, possible to select, with appropriate tests, the individuals who are naturally qualified for exacting night duty, and to eliminate the unfit.

This is but an instance of one of the most important responsibilities of the flight surgeon in a technological war. By nature all men are not equal; the more exacting their tasks, the more important does it become to select those best fitted for specific duties. And so the medical services of the Air Forces have during the last 30 years developed searching tests to determine the physiological fitness of an individual to meet the stresses of aerial combat. But even these fail at times to reveal some subtle incapacity, and we have accordingly added to those tests certain realistic examinations under actual conditions of environmental stress. Such is the observation in an altitude chamber of each prospective airman for abnormal reactions to high altitude. If he reacts unusually to mild lack of oxygen, he may be rejected; for temporary emergencies arise with even the best oxygen supply equipment. Or an individual who is especially susceptible to pain during decompression is limited to low altitude operations.

Beyond these more obvious physiological characteristics of his constitution are the mental, emotional, and temperamental aptitudes of the candidate. The demands of constant attention to exacting operations, the frequent necessity for quick decisions of vital importance, and the constant threat of disaster place a severe nervous strain on an airman. Those who are considered to be incapable of withstanding these stresses are eliminated. But even those who must be judged mentally normal ultimately face severe threats to their endurance. To ease their strain, the medical examination of airmen has been broadened to include a psychological assessment of a candidate's intellectual qualifications and his special aptitudes. Thus, the fitness of an individual for the highly technical work of aerial war is judged by an appraisal of the man as a whole—physically, mentally, and temperamentally. The chances of his success in his job depend upon the accuracy of this appraisal. Even more important to the flight surgeon is the fact that the chances for good mental health are better if the man is given the work for which he is best fitted, and the danger of accidents or sickness is less.

In a series of psychological research units each trainee is carefully assessed by interviews, written examinations, and psychomotor manipulative tests. Those who demonstrate good judgment, facility in learning eye-hand coordinations, and a high degree of emotional stability, with qualities of leadership, are preferred as pilots; accuracy of motor coordination in the execution of precise manipulations and a quick reaction time meet the requirements for a bombardier; an interest in

mathematics and logical, precise habits of thinking suggest assignment as a navigator.

That the psychological examining stations are referred to as "research units," indicates the exploratory and experimental nature of this program. Criteria for acceptance into air-crew training and for assignment to specialized duties are frequently reviewed, so that the predictions shall be as accurate as possible. To accomplish this, the tests are constructed so as to meet the needs of the operations for which men are being selected. And the predictive accuracy of the tests is, from time to time, checked against subsequent performance, by assigning groups of men to duties without taking into consideration the psychological evaluation of their aptitudes.

The evidence gained from one large, typical group demonstrates the extraordinary value of this program of selection and classification. From among those of this group who had been judged by the psychologists to be best qualified for the duties of a pilot, only 4 percent were eliminated by the flight instructors during primary pilot training, whereas 78 percent of those who had been considered unsuitable by the psychologists were "washed out" by the instructor. There was a similar accuracy of prediction for the subsequent performance of navigators and bombardiers. Also of medical significance is the value of this selection in the reduction of flying accidents. The 15 percent considered least qualified for pilot duty, on the basis of the psychological tests, had three times as many accidents during pilot training as had those cadets who had been judged to be the 30 percent best fitted for their duties.

I have dwelt at length on the human problems created by modern combat aviation. To these I might add certain others which arise from the wide-flung system of the Air Transport and Troop Carrier Commands. Quick movement from the Arctic to the Tropics subjects men to sudden changes of climate; forced landings in remote places taxes man's capacity to survive in strange and isolated environments; swift transportation of many troops favors the spread of geographically restricted diseases. But each problem has been met by the application of medical and physiological knowledge, and from this swift transportation has come a new advance in the practice of military medicine.

The same planes that carry weapons of destruction and personnel to the battlefields bring back the sick and wounded, quickly and safely. Within a few hours after injury, a man may be hundreds of miles behind the lines in the security of a well-established hospital, where he is able to receive the best of modern medical and surgical treatment. The improvised surgery of the field station and the slow agony of hospital trains that tortured the body of the wounded and the patience of the tactician, concerned with his supply lines, may soon be only

memories of the past. For in 1943 the Army Air Forces evacuated by air 173,527 sick and wounded patients (a figure that is not to be confused with announced battle casualties) with only 11 deaths in flight. This amazingly low death rate of 0.006 percent is effective refutation of those who doubted the medical feasibility of the Air Surgeon's farsighted proposals in 1939 for the creation of air evacuation squadrons.

An important element in the success of this undertaking has been the employment of air transport cargo planes and troop carrier planes, rather than specially assigned aerial evacuation planes. By using the return flights of the cargo and transport aircraft, equipped with removable litters, planes have been conserved, and, what is more important, our aerial ambulances have been available wherever there is action. Once again, aviation has reshaped the strategy of warfare and has given new advantages that reduce the sufferings of combat.

Few will be as bold now in predicting the future course of military aviation as was the founder of the American Philosophical Society in 1783, when he watched Pilâtre du Rozier make the first balloon ascent. "This new invention may possibly give a new turn to human affairs," said Benjamin Franklin. "It may convince sovereigns of the folly of wars, since it will be impractical for the most potent of them to guard his dominions. Five thousand balloons capable of raising two men each could not cost more than five ships of the line; and where is the prince who can afford so to cover his country with troops for its defence as that 10,000 men descending from the clouds might not in many places do an infinite deal of mischief before a force could be brought together to repel them." Franklin's forecast may still prove correct, and the great aerial assaults of today may indeed "convince sovereigns of the folly of wars." If that comes to pass, it will be the greatest of aviation's notable contributions to human welfare.

BLOOD AND BLOOD DERIVATIVES¹

By EDWIN J. COHN

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[With 1 plate]

Our understanding of the circulation of the blood followed the rapid development during the sixteenth and seventeenth centuries of our knowledge of anatomy. William Harvey (1578-1657) studied at Padua where the Chair of Anatomy had been held successively by Vesalius, by Realdo Columbus, by Gabriele Fallopio, and by Fabricius of Aquapendente, the latter carrying on the tradition in Harvey's time. Returning to England, Harvey continued his studies and published his great work "De Motu Cordis" in 1628.

Our understanding of the cellular composition of the blood followed the development of the microscope. Leeuwenhoek (1632-1723), fascinated by the phenomena revealed by the lenses he ground, achieved magnifications with the aid of which he described the blood corpuscles first in the frog and then in man.

Comparably, our understanding of the molecular composition and the multiple functions of the blood is following the beginnings in the nineteenth century and the rapid development in the twentieth of protein chemistry. Just as the development of the microscope made it possible to distinguish the cellular elements of the blood, so advances in the methods of protein chemistry are making it possible to distinguish a large number of substances dissolved in the blood, each with different physicochemical and physiological properties. The separation and concentration of these substances make possible a new mastery and give promise of a new therapeutic control of the composition and the functions of this complex body fluid.

Blood has always been accorded a unique status in the minds of men. It was early associated with the seat of the soul. The Bible distinguished repeatedly between the tissues and the blood. Association with the spirit of man is further attested by the large number of ex-

¹ From American Scientist, vol. 33, No. 2, 1945 (reprint from Science in Progress, Series IV, April 1945), and here reprinted by permission from The Society of the Sigma Xi and Yale University Press.

pressions in which special attributes of men are associated with the nature and quality of their blood. One said of a nobleman or of a criminal that it is "in his blood"; of the calm and calculating that he is "cold blooded"; of the well-born "blue blooded"; of the closeness of family ties "blood is thicker than water." The scientific evidence, as we shall see when we consider the viscosity of blood, is adequate to prove the latter contention, but despite the great advances that have recently been made, it is not yet possible to distinguish chemical attributes of the blood which could form the basis for the other expressions, residues of the folklore of blood.

When Mephistopheles demands of Faust that he sign the compact pledging his soul in blood, Goethe has Mephistopheles explain to the protesting Faust that "blood is a juice of rarest quality." Goethe's Faust appeared at the beginning of the nineteenth century. Marlowe's Doctor Faustus goes less far in freeing blood of its biblical and medieval mysteries by ascribing to it peculiar properties as a juice or body fluid.

The mysteries that have always been ascribed to the blood have not been entirely solved by modern science. Blood performs more functions than we have learned to ascribe to the substances in it that we recognized. We now recognize many substances in the blood whose functions are not yet understood. We may hope, however, to resolve these mysteries by increasing our knowledge of this "juice of rarest quality" which is the circulating fluid of the body.

THE RED CELLS AND THE RESPIRATORY FUNCTION OF THE BLOOD

This circulating fluid contains cellular elements of various kinds. Most important among them are the erythrocytes or red cells and the leukocytes or white cells. The red cells perform the respiratory function of the blood; the composition and functions of the white cells are less well known but are generally associated with phagocytic activity.

The circulating blood is in equilibrium with all the tissues of the body. Anatomists had explored the distribution of arteries, capillaries, and veins, and Harvey demonstrated the circulation of the blood propelled by the heart through this complex system. Nineteenth-century physiology recognized and investigated the interchange between the various tissues and the blood which Claude Bernard called the *milieu intérieur*, or internal environment. Considered from the point of view of respiration, the blood carries oxygen to the tissues and removes carbon dioxide and other waste products from them. The mechanism for oxygen transport is not only situated within the red cells but can be associated with certain specific proteins that they contain.

Proteins are among the largest known molecules. All living tissue contains proteins and the complexity of the protein molecule is such that its synthesis in the laboratory is not yet envisioned. However, it is synthesized in processes of biological growth, and the shape and functions of the tissues may be thought of as depending in large part upon the shape and structure of the proteins of which they are composed.

The protein within the red cells, which gives blood its color and performs its prime respiratory function, is hemoglobin. Proteins are largely composed of nitrogen, carbon, hydrogen, and oxygen organized in the more than 20 different amino acids which are the building blocks of proteins. Hemoglobin contains hundreds of amino acids held together by chemical combination, with loss of water, of the amino and carboxyl groups which all possess. The synthesis of protein in the body is balanced by hydrolysis of these same links which thus confer lability as well as specificity of structure upon these vast protein molecules.

Hemoglobin performs its specific respiratory function by virtue of a relatively small prosthetic group, attached to the molecule but readily separated from it, which is not composed of amino acids but of iron in a configuration of pyrrole rings. The iron in this configuration has a high avidity for oxygen, combines with it, and is the means of its transport. The prosthetic group containing the iron is called heme, the protein part of the molecule globin.

Let us examine the relative masses of the oxygen needed by the tissues and the various component parts of the mechanism which the body employs for its transport. The atomic weight of oxygen is 16 and of iron 55. Each iron atom combines with an oxygen molecule, that is, 2 oxygen atoms. The iron, however, is part of the heme group with a combining weight close to 700. The heme is attached to the globin, each iron to a unit of 16,700 equivalent weight. Iron-containing proteins concerned with respiration in muscle, known as myoglobin, are of this size, but the hemoglobin of the blood stream has a molecular weight of at least 33,400 and generally of 66,800, in the former state combining and transporting 2, in the latter 4, oxygen molecules. The molecule devised by nature for the efficient transport of oxygen to the tissues thus has a mass roughly 500 times that of the oxygen molecule to be transported.

Why is the hemoglobin of the blood stream contained within cell walls? The proteins which perform comparable respiratory functions in many forms of life are free in the fluid part of the blood. The proteins dissolved in the fluid part of the blood of animals rarely exceed 10 percent, those dissolved in the fluid or plasma part of the blood of man, 7 percent. This figure may be contrasted with the 30

percent of hemoglobin contained in the red blood cell. Were this concentration of hemoglobin free in the blood stream, it would bring about a redistribution of many other components than oxygen. It is the way of the body, or appears to be to those concerned with the study of its mechanism, to evolve processes which in enhancing the efficiency with which certain functions are performed do not inhibit others.

The function of transporting oxygen by the hemoglobin within the red cell involves a complex mechanism permitting maximum combination with oxygen in the lungs and release of oxygen in the tissues. As carbon dioxide increases, the hemoglobin unloads the oxygen which it has transported. Another protein, an enzyme, carbonic anhydrase, accelerates and renders more efficient this process. In addition, the red cells contain other enzymes, including a catalase and a phosphatase. The presence of these enzymes suggests the nature of certain of the chemical reactions which are involved in the internal economy of these cells. These vital processes also appear to limit the life of the red blood cell. For the life of the red cell, estimated to be roughly 3 months in the blood stream, is limited in the blood bank, under even the best methods of preservation at present known, to approximately a month.

No other part of human blood has so significant a function in transporting oxygen to the tissues, in permitting the very great activity and high order of mammalian respiration. Therapeutically, therefore, when there is great blood loss from a wound, when a major operation is to be performed, or when the anemia which frequently occurs in convalescence from wounds must be combated, red blood cells must be supplied in amounts adequate to restore the oxygen-carrying capacity of the blood.

On the other hand, the lability of the red cells renders it difficult to develop a reserve of whole blood which can be transported to the theaters of operation at great distances and stored indefinitely against the uneven needs of a military campaign. There are, moreover, many functions of the blood other than those of oxygen transport. These can be supplied by other parts of the blood, the more labile red blood cells being conserved for therapy for conditions in which they alone suffice.

PLASMA AND THE PLASMA PROTEINS

Blood is readily separated into cellular and noncellular parts by centrifugation. The heavier cellular elements are easily thrown to the bottom when the bleeding bottle is spun in a cup centrifuge. The supernatant fluid is clear, amber colored, and is called the plasma. The separated red cells occupy something less than half the total volume; the plasma, the body fluid in which they are suspended in nature, some-

thing more than half the volume. The proportion of the blood occupied by the red cells varies somewhat from individual to individual. If the red cells are too few in number, the condition of anemia obtains; if they are too concentrated, the viscosity of the blood is increased, and an extra burden is imposed on the heart in forcing the blood through the circulatory system.

Shock as observed in military medicine generally results from a rapid decrease in the volume of circulating blood due to the loss of blood and plasma proteins externally and into damaged tissues. It is most frequently treated, or prevented, by injection of plasma protein. The injected proteins, insofar as they cannot readily pass through the kidney, increase the body's reservoir of plasma proteins and, insofar as they do not readily transverse the capillary walls, increase the plasma volume by drawing water from the tissues into the blood stream, and by holding it there.

The maintenance of the fluid balance between the blood and the tissues is one of the functions of the plasma proteins. While they are like hemoglobin in their general organic structure, their special properties and their functions differ widely from hemoglobin or globin. Moreover, there are many different kinds of plasma proteins, each serving a different function. The function of controlling the equilibrium between the water and the electrolytes in the blood and in the tissues is largely performed by the smaller proteins of the blood stream, known as the albumins, although all dissolved colloids will, of course, exert some osmotic effect.

Osmotic pressure is the force exerted by the dissolved molecules so large that they cannot pass through the pores of the membranes that contain them. The walls of the blood vessels are the retaining walls for the plasma proteins. Oxygen, water, electrolytes, sugars, and other small molecules readily pass these walls. But normally the plasma proteins do not, nor do they pass the kidney and appear in the urine. A variety of conditions influence the permeability of membranes to dissolved molecules. Besides the size and shape of the molecules, these include the charged state of the membranes as well as of the molecules and the nature of their surface groups. The limiting condition for passage through a membrane is, however, the size of the pores and the size of the dissolved molecule.

The plasma proteins vary in mass and in length. All that have been adequately studied, however, have closely the same diameter, ranging from 33 to 38 angstrom units (an angstrom unit being 10^{-8} cm.). The albumin molecules are the most symmetrical of the plasma proteins, being approximately four times as long as their diameters. (See table 1.)

TABLE 1.—*Relative dimensions of NaCl, glucose, hemoglobin, red blood cells, and the various plasma proteins*

	Approximate dimensions (Ångstroms)		Viscosity coefficient	Molecular weight
	Length of ellipsoid	Equatorial diameter of ellipsoid		
Sodium ion	1.9	1.9	..	23
Chloride ion	3.6	3.6	..	35.5
Glucose	9.5	6.5	4	180
Hemoglobin	118 155	28 32	.. 5.1	39,000 68,000
Red blood cells	24,000	86,000	4	..
Serum albumin	150	38	5.8	69,000
Serum γ -globulin	320	36	8.5	156,000
Fibrinogen	900	33	70	500,000

Among plasma proteins certain of the globulins are twice as long as the albumins, and the protein that forms the matrix of the blood clot, fibrinogen, is a rod-shaped molecule 6 times as long as albumin. Fibrinogen is almost 30 times as long as its diameter. Its solutions are therefore extremely viscous, viscosity being a function not of the size of molecules but rather of their asymmetry. Fibrinogen is present in the plasma, however, to only 0.24 to 0.3 percent, representing 4 to 5 percent of the plasma proteins. By contrast, the albumins represent 55 to 60 percent of the plasma proteins, are by far the most soluble, and their solutions are the least viscous.

Elementary considerations indicate different ways in which the size and shape of the plasma proteins influence the blood. The osmotic

RELATIVE DIMENSIONS OF VARIOUS PROTEINS

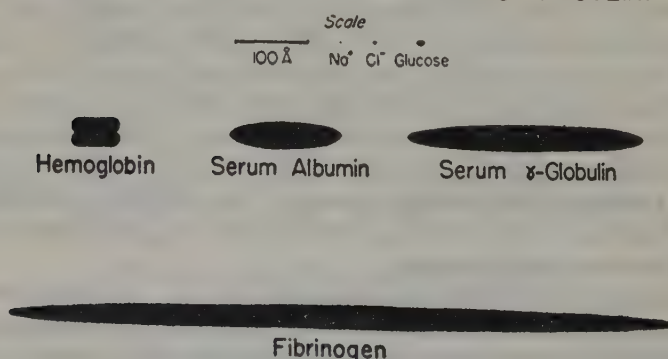


FIGURE 1.—Relative dimensions of various blood proteins. If the serum albumin molecule were the length of this page, a red cell would be the size of a football stadium. A value of about 6,000,000,000,000 is obtained for the weight of Avogadro's number of red blood cells, which are therefore about a billion times the weight of a serum albumin molecule. Values: hemoglobin, 68,000; serum albumin, 69,000; serum and globulin, 156,000; fibrinogen, 500,000. Scale models and many of the estimates by Oncley.

pressure is, as a first approximation, a function of the number of dissolved molecules to which the membrane is impermeable. Since the blood vessels are impermeable to the normal plasma proteins they exert sustained osmotic pressure. Since these proteins cannot pass through the membranes their presence in the blood stream holds water in it in an amount roughly proportional to their concentration, more exactly to their effects on the osmotic pressure.

Should an increase in permeability of the blood vessels occur which is sufficiently great to allow plasma proteins to escape into the tissue spaces, fluid will also pass into the tissue spaces. Commonly such a change in permeability occurs where there has been a severe burn or injury and usually is not sufficiently great to permit many red cells to leave the blood stream. As a result, there is an increase in red cell concentration (often measured in terms of a hematocrit reading), an increase in viscosity, and a decrease in the volume of circulating plasma. This diminution of blood volume ultimately results in poor peripheral circulation and hence inadequate oxygen transport, while the increased viscosity makes it more difficult for the heart to move the remaining blood through the blood vessels. This condition may be overcome by injecting into the blood stream molecules which will not readily leave it and which, by exerting osmotic pressure, will pull water back into the blood stream, decrease viscosity, and permit a return to normal circulation of the blood with the transport of oxygen to the tissues and the fulfillment of the other physiological functions of the blood.

The diameters of all the plasma proteins are so nearly the same that a change in permeability that will permit one type of protein to pass a membrane will generally permit all to pass. The amounts of each protein type that will pass will, however, now depend upon other factors controlling permeability. Thus the longer molecules will on the average leave the blood stream less readily than the more symmetrical albumins. The electrically charged conditions of the molecules will also play a role. The albumins bear the largest negative charges, and a species of globulins, known as the γ -globulins, precisely because of their low negative electrical charge in neutral solutions, the lowest.

The plasma proteins that leave the blood stream and appear in the urine or in the tissue spaces, under a variety of conditions, might be expected to reflect all these influences. It has been repeatedly noted by various investigators under various conditions that the distribution of proteins lost from the blood is far more nearly constant than the composition of the plasma under pathological conditions. It is more nearly characteristic of normal than of pathological plasma. Gen-

erally it is the albumins and the γ -globulins that appear to be lost more readily than either other globulins of larger net charge or fibrinogen. The significance of this observation is twofold. On the one hand, it reflects the conditions that obtain when proteins leave the blood stream, on the other the replacements that must be made if normal composition of the blood is to be restored by therapy.

Although the smallest plasma proteins of largest net charge, the albumins, and the largest globulins of smallest net charge, the γ -globulins, leave the blood stream most readily, it is the albumins which have the largest effect in controlling the equilibrium in water and electrolytes between blood and the tissues. The γ -globulins represent but 11 percent of the plasma proteins, the albumins five or more times that much. The molecular weight of the γ -globulins is two or more times that of the albumins. On the basis of mass alone, therefore, the γ -globulins—which as we shall see are the bearers of the immune properties of the blood—contribute less than one-tenth as much as the albumins to maintaining the volume of the blood. This calculation neglects the greater contribution of the albumins which depends upon their greater net charge. Indeed, albumins are responsible for nearly 80 percent of the osmotic activity of the blood. Accordingly it is the albumins in plasma which are in large part responsible for the therapeutic value of plasma in the treatment of shock.

The fact that fibrinogen leaves the blood more slowly than albumin may be associated with its greater length. On the whole, molecules of the same diameter should pass an inert membrane inversely as their length. The presence of fibrinogen in the blood in small amount must be associated with its special functions, which we shall examine later in connection with the clotting of the blood. Its osmotic contribution is negligible but its contribution to viscosity is enormous and this effect might be deleterious were fibrinogen present in large amount. Under these circumstances, it brings about clumping of the red cells as do many other highly asymmetric molecules.

If substances other than the plasma proteins are injected into the blood, their fate also appears to depend upon their dimensions. Saline, glucose, and most substances that have thus far been suggested as blood substitutes have diameters less than 20 angstrom units and, unless they are very asymmetrical, leave the blood stream rapidly. They thus exert temporary, but do not have sustained, influence in maintaining blood volume.

Asymmetric molecules appear to leave the blood stream more slowly and may even accumulate in the blood stream as evidenced by their influence on the clumping and sedimenting of red cells. Such mole-

cules increase the viscosity of solutions and may well bring about abnormal distribution of plasma proteins. It is by no means certain, therefore, that the retention of foreign substances of this kind in the blood stream is beneficial.

From a physicochemical point of view, it is possible to understand, at least as a first approximation, certain of the phenomena of plasma loss. Since all the plasma proteins have about the same equatorial diameter, any change in the permeability of a membrane which would permit one plasma protein to diffuse through it should permit any of them to do so. Under these circumstances, the amount of plasma protein of each type to diffuse should be an inverse function of their length. Consequently for a given change in permeability there will be a greater loss—and therefore a greater need for replacement—of albumin than of the globulins or fibrinogen.

Clearly there is a principle guiding the amount of any plasma component that may wisely be used in replacement therapy, namely, the amount that will tend to reestablish rather than to derange the normal concentrations of the various physiologically significant plasma components.

CHEMICAL FRACTIONATION OF THE COMPONENTS OF PLASMA

The highly specialized structure of the plasma proteins indicates that each has a special function and that their colloidal properties, which alone have thus far been considered, are but superficial manifestations of their intrinsic nature.

The proteins, as their name implies, are "of the first importance," and this importance extends equally to the structure of cells and to the processes of life. The role of these nitrogen-rich substances in the nutritional cycle of plants and animals has long been appreciated. Indeed, the elementary composition of "blood albumin" and "blood fibrin" were being studied by the group of chemists that collected around Liebig just over a century ago, and in 1841 Denis, a French scientist, communicated to Liebig the separation of blood proteins into albumins and globulins.

Though less labile than cells, proteins also are labile. The molecules that occur in nature were until recently not readily separated, purified, concentrated, or dried, without change of structure or loss of function, by the conventional methods of chemistry.

TABLE 2.—Whole blood

	Principal function	Principal protein related to function	Concentrated in plasma fraction	Plasma protein in fraction	Concentration of active function times that of plasma		Established clinical use
					Per gm. protein	Per cc. product	
RED CELLS (45% of blood containing 30% hemoglobin)	Respiratory	Hemoglobin					Whole blood or red cell transfusion.
	Osmotic regulation of blood volume	Albumin	V	48	1.3	5.4	Shock, burns, edema, hypoproteinemia.
	Blood coagulation	Fibrinogen	I	6	21	..	Fibrin films as dural substitutes.
PLASMA (55% of blood containing 7% proteins)		Prothrombin, thrombin	III-2	3	20	..	Fibrin foam and thrombin as hemostatic agent.
	Immunological	Blood grouping globulins Complement C'1 C'2	III-1 III-2 IV II	3	24	36	Blood grouping.
	Carbohydrate and lipid solution and transport	γ -globulins	III	..	15	..	
		β globulins	IV	..	8	..	
		α -globulins	IV	6	8	25	Measles prophylaxis.
Regulatory		Fibrinolytic enzyme	I, III-2				
		Phosphatase and other enzymes Hypertensinogen Thyrotropic hormone Gonadotropic hormones	III, IV IV-3, 4 IV-3, 4 III, VI	10			

The methods of the nineteenth century have been largely supplanted by recent developments in the preparative chemistry of the proteins and upon two of these are based the preservation and accumulation as against military needs in distant theaters of operation of the plasma proteins separated from the blood collected by the American Red Cross.

The first of these methodical developments is the drying of proteins from the frozen state. Proteins coagulate at elevated temperatures and in the presence of the organic solvents generally used in drying ordinary chemicals. Likewise, denaturing changes often take place when proteins are dried at ordinary temperatures. A body of investigation has demonstrated, however, that such changes are minimized when protein systems are first reduced to the frozen state and water then removed under reduced pressure by sublimation. The dried plasma which has so successfully been used by our Armed Forces in every theater of operation is rendered stable by this technique. The plasma is reconstituted just before use by addition to the dried powder in one bottle of the diluent transported in another bottle in the same package. All but the most labile components of plasma may be preserved by this process, whereas all but its colloidal attributes are lost if liquid plasma is preserved for long periods of time even at low temperatures.

TABLE 3.—*Distribution of proteins of plasma*¹

	Grams protein per liter plasma	Grams protein per liter of plasma in fractions				
		I	II+III	IV	V	VI
Protein	60.3	4.3	16.3	9.7	29.6	0.6
Albumin	33.2	0.2	0.7	1.0	29.0	0.3
α -Globulin	8.4	0.2	1.8	5.4	0.6	0.3
β -Globulin	7.8	0.8	6.2	3.1	..	..
γ -Globulin	6.6	0.5	6.0	0.2	..	..
Fibrinogen ²	4.3	2.6	1.6	..	..	..

¹ Cohn, Oncley, Strong, Hughes, and Armstrong.

² Estimated by electrophoresis. The amount of clottable protein is always lower and probably more reliable. See Edsall, Ferry, and Armstrong.

The second development has made possible the quantitatively reproducible fractionation of plasma by new chemical methods which on the one hand are susceptible to the large industrial scale that has been necessary to process the blood of over one and one-half million Red Cross donors, on the other to yield as final products plasma proteins of unimpaired function.

The potential value of all the different proteins of human plasma demanded that this process be inclusive in the sense that all components be separated and concentrated. The present process separates the plasma into five fractions. (See fig. 2.) Fraction I is rich in fibrinogen. Fraction II consists of γ -globulins, which are the chief bearers of immunity in the blood. (For convenience in manufacture, Fraction II + III, which contains essentially all the γ -globulins, is first sepa-

rated as one and then subjected to subfractionations.) Fraction III-1 contains those euglobulin components of plasma, the isoagglutinins, which interact with the red cells according to their specific blood groups and which, therefore, can be used in the typing of blood. Fraction III-1 is also rich in certain lipo-proteins containing all the carotenoids and a large part of the cholesterol. Fraction III-2 is

PLASMA PROTEINS

THEIR NATURAL FUNCTIONS AND CLINICAL USES AND SEPARATION INTO FRACTIONS

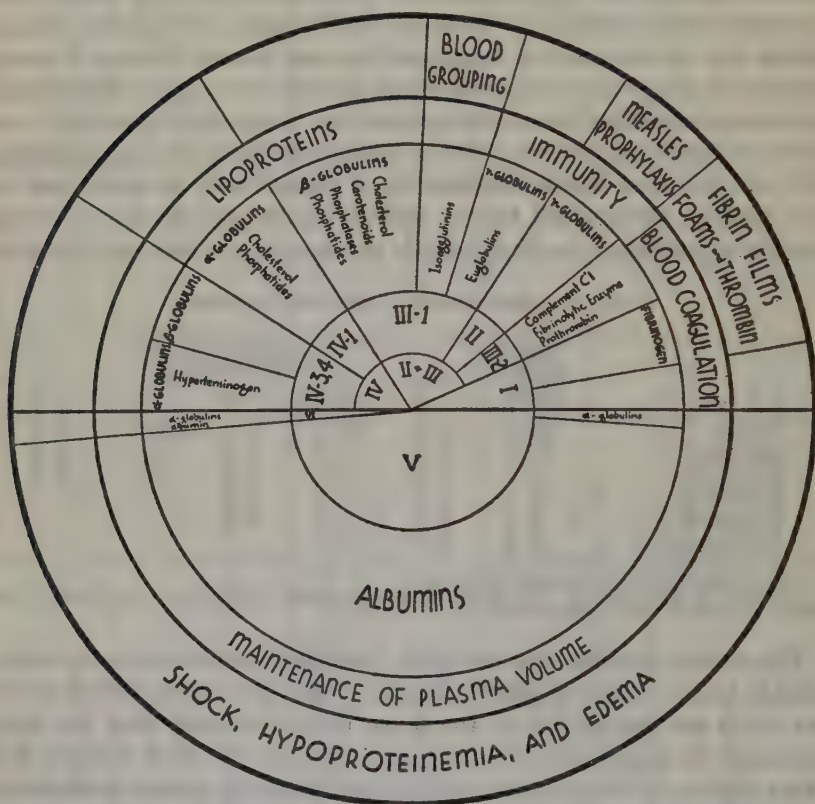


FIGURE 2.—Plasma proteins: their natural functions, clinical uses, and separation into fractions. (Courtesy of Science.)

largely β -globulin and contains components important in blood coagulation, among them thrombin, prothrombin, and a fibrinolytic enzyme. Fraction IV contains the remaining β -globulins and most of the α -globulins. Of these α -1 is further separated into Fraction IV-1. Fraction V contains between 85 and 90 percent of the albumin. The mother liquors in Fraction VI contain about 1 percent of the total

proteins. The yields of the proteins in the various fractions are given in table 3.

The fractionation of plasma into its component parts according to this process developed in the Department of Physical Chemistry of the Harvard Medical School has been carried on in seven commercial laboratories under contract with the United States Navy. The albumin of plasma represents by far its largest component and is concentrated therefore in its largest fraction, V. Whereas there is evidence of the existence of more than one albumin, this fraction appears homogeneous in the ultracentrifuge and in the electrophoretic apparatus at neutral or slightly alkaline reactions. The standard of purity specified in the Navy contracts for the production of this blood derivative permits 2 percent of globulin. Electrophoretic analyses reveal the constancy of the product under the conditions of industrial production.

Human serum albumin has been still further purified by crystallization, and study of the crystallized albumin that we have prepared has demonstrated that the very high thermal stability and low viscosity of our standard preparations are indeed ascribable to the albumin, instability largely to globulin and lipid impurities.

Normal human serum albumin can be prepared in far larger amounts and with higher yields if further purification by crystallization is not superimposed upon the process. The standards of purity determined upon for the albumin now being delivered to the Navy in large amounts were chosen so as to assure freedom from untoward reactions with maximum efficiency in large-scale production.

Serum albumin was developed in order to attain a blood derivative which could be distributed in solution ready for immediate emergency use. It has been made available as a 25-percent solution to render the package as compact as possible for transport. Osmotically more than four times as concentrated as plasma, 25-percent albumin is no more viscous than whole blood. The package developed by the Armed Forces for the standard 25-percent albumin solution occupies one-sixth the space of the osmotically equivalent plasma package.

ALBUMIN AND THE CONTROL OF THE BLOOD VOLUME

That the value of plasma in controlling the volume of the blood depends upon its osmotic activity is beautifully demonstrated by the studies that have been carried out on the osmotic pressure of plasma and of albumin solutions. These measurements yield a molecular weight of 69,000 for albumin and an average weight of about 170,000 for the 40 percent of the protein which is not albumin. Each gram of albumin is equivalent to 1.2 grams of plasma protein or to 20 cubic centimeters of the current Red Cross citrated pooled plasma. The volume of fluid held in the blood stream by each gram of albumin should be about 18 cubic centimeters (table 4).

TABLE 4.—*Osmotic effect of concentrated human serum albumin in increasing blood volume*

Conditions of measurement	Increase in blood volume per gram albumin
	cc.
Estimated from osmotic pressure ¹	18
In experimental hemorrhage ²	17
In clinical shock, after $\frac{1}{2}$ –1 hour ³	16
In clinical shock, after 1–36 hours ⁴	23

¹ Scatchard, Batchelder, and Brown.² Heyl, Gibson, and Janeway.³ Warren, Stead, Merrill, and Brannon.⁴ Courmand, Noble, Breed, Lauson, Baldwin, and Richards.

The results of these osmotic-pressure measurements may be compared with the clinical findings of three groups that have made independent studies on the value of albumin for transfusions, especially in shock. All have determined the water drawn into the blood stream following injection of albumin in man. One group reported that "the average increase" in blood volume (1 hour after injection) "was 17.4 cubic centimeters per gram although there was considerable variation between individual experiments." Another reported that "the albumin injected into the circulation is largely retained, providing no further bleeding or exudation of plasma occurs. It is still remaining in the circulation at the end of 6 hours. The albumin retained holds in the blood stream amounts of fluid approximately comparable to its osmotic activity. Thus, in our series, 1 gram of albumin retained resulted in an average increase of plasma volume of 23 cubic centimeters." The third group concluded that "the plasma volume increased 600, 800, and 900 cubic centimeters in the patients receiving 50 grams of albumin. The average increase in volume was 16 cubic centimeters for each gram of albumin." These three carefully controlled clinical investigations yielding respectively 17.4, 23, and 16 cubic centimeters drawn into the blood stream of patients per gram of albumin injected must be considered in excellent agreement with the expectation from the osmotic-pressure measurements of 18 cubic centimeters per gram of albumin which forms the basis for the osmotic equivalence of the two blood derivatives, plasma and albumin, being dispensed to the Armed Forces.

α- AND β-GLOBULINS AND THE HORMONES, ENZYMES, AND
LIPO-PROTEINS OF THE BLOOD

Although the albumins of plasma play far more important roles than the globulins in the control of blood volume, the diverse globulins also perform functions for which they appear to be uniquely designed.

The number of such globulins is far larger than our present physico-chemical criteria for their characterization. Moreover, certain of them appear to be present in very small amounts—amounts, however, adequate to perform their natural functions. In diseases in which there is a deficiency of any of these proteins, however, it would appear to be of the utmost value to have them available, separated from the plasma and concentrated as specific therapeutic agents.

The blood of man is rich in lipid as well as in protein material. Only a small amount of this lipid is present in an emulsified state; most of it is held in solution in more or less labile combination with the various plasma proteins. Among the lipids that are readily distinguished are cholesterol, carotenoids, phosphatides, and cerebroside. Of these the carotenoids are found concentrated with certain β -globulins in Fraction III (see table 2) which is also rich in cholesterol. Cholesterol, phosphatides, and cerebroside have also been found concentrated with α -globulins in Fraction IV. Here our study of plasma proteins is leading us to a study of the plasma lipids, not as organic chemicals separated from blood by methods which destroy the structure of the lipo-proteins but in the state in which they exist in nature. Their separation and purification as protein complexes should make possible investigation of their function and an increasing understanding of their role in the economy of the body.

The economy of the body is controlled by a group of messengers, hormones, secreted and liberated by various glands. These hormones also find their way into the blood stream and some of them have been identified, although they are present in but very small amount. Among them is the thyrotropic hormone which appears to be closely related to that secreted by the anterior pituitary gland. The gonadotropic hormones secreted by this gland have also been identified in one or another plasma fraction. As our survey of the hormones in the blood expands it should be possible not only to concentrate and recognize more of them but also to make them available as concentrates should they prove to have any value in therapy. Their human origin should make it possible to use hormones derived from man when those derived from animals lead to sensitization following repeated injection.

The economy of the body is aided also by a series of enzymes whose specific function it is to accelerate chemical reactions. The blood stream contains many such enzymes. A cholinesterase and phosphatase clearly have functions related to the cerebroside and phosphatides of the blood stream. Phosphatides of more than one kind have been recognized both within and without the red cell. There are lipases and proteolytic enzymes and the number of these is not yet clearly defined. One, the fibrinolytic enzyme, will serve to illustrate a principle that applies to others. The blood stream carries not only

components necessary to form a clot instantly at a bleeding surface, but also this enzyme capable of dissolving the clot.

FIBRINOGEN, THROMBIN, AND THE CLOTTING OF THE BLOOD

The clotting mechanism of the body is indeed complex. The structural element of the clot is the long rod-shaped fibrinogen molecule which is dissolved in the plasma. Its aggregation and separation as the fibrin clot are carried out by the globulin, thrombin. When thrombin and fibrinogen are mixed *in vitro*, a clot immediately occurs. Thrombin, however, does not exist free in the blood stream but as a precursor substance, prothrombin, readily transformed into thrombin in the presence of calcium by tissue extracts known as thromboplastins.

The various parts of this complex mechanism may be separated and concentrated and made available in various forms. By controlling the conditions of the reaction between fibrinogen and thrombin, structures of a wide variety of properties can be obtained. Clots of one type are clear, gelatinlike, elastic, and friable, do not readily synerize with loss of fluid, and adhere to surfaces on which they are formed. Clots of another type are opaque, doughy, and scuff-resistant, synerize readily, become dense with loss of fluid, and do not adhere to underlying surfaces. Clots of intermediate properties can also be made.

For surgical use in human patients, clots may be prepared from fibrinogen and thrombin to meet the particular specifications chosen for each type of application, and may be formed *in situ* in or over wounds. Clots whose properties have been controlled in this way have been used in pyelolithotomy and in a technique for skin grafting.

Just as the asymmetry of certain synthetic polymers is responsible for the remarkable mechanical properties of industrial plastics, the fibrinogen molecule endows products of this human protein with remarkable mechanical properties. Among these products is fibrin film. Fibrin film may be prepared from fibrinogen and thrombin as a strong, rubbery sheet which can be stretched reversibly from two to three times its original length. This material can be made in various shapes and thicknesses, and in the form of seamless tubing. Its mechanical properties can also be varied from a soft, rubberlike elasticity to a parchmentlike consistency.

The mechanical properties of the soft, rubbery films (as shown by their stress-strain curves) bear a marked similarity to those of the elastic ligament of the neck, the *ligamentum nuchae*. The tough films with delayed elasticity resemble rather wool or hair in their mechanical properties. It may be possible to imitate, with different types of fibrin products, still other natural structures of the body.

The fine structure of fibrin film has been shown to involve pores which in one type are of the order of 60 angstrom units in diameter. Hemoglobin molecules in solution pass through these pores readily, but plasma globulins are partially and fibrinogen molecules completely retained.

The mechanical properties of certain types of fibrin films make them suited for use as dural substitutes and in the prevention of meningo-cerebral adhesions. The duration of their persistence in the body can be adjusted by suitable treatments. They have been used in neuro-surgical operations and appear to be an excellent material for these purposes, patients having been followed for as long as 15 months without the appearance of unfavorable sequelae. Other types of fibrin film and of fibrinogen plastics are being tested for other surgical applications.

For stopping the flow of blood, in surgical procedures, thrombin is the only component of the clotting mechanism which must be supplied. For the most effective use of thrombin in hemostasis, however, it must be applied with a matrix which can hold the thrombin in the bleeding area until clotting is completed. A porous matrix soaked in thrombin solution can accomplish this mechanical result. Fibrin foam is such a matrix formed from human fibrinogen and thrombin. It effectively controls bleeding from oozing surfaces and from veins, even very large ones. Though not recommended for brisk arterial hemorrhage, it has proved very effective in neurosurgery in controlling hemorrhage from the dura, from tumor beds, from dural sinuses, and from large cerebral veins. In general surgery it has been reported effective, in a small number of patients, in controlling hemorrhage from the cut surface of the liver and kidney, in jaundiced patients, in thoracic operations, and in stopping bleeding in hemophilia.

In the dry state fibrin foam is a porous material composed of strands of fibers separated by air spaces of macroscopic size. It readily absorbs water, saline, or thrombin solution, and can be used in conjunction with a sulfa drug or with penicillin. The physical properties of the foam, as of the film, can be varied by controlling the conditions of manufacture. Since fibrin foam is prepared completely from human proteins and is rapidly absorbed with minimal tissue reaction, it is left in place, thus preventing recurrence of bleeding. It is easily handled in the operating room, and, like serum albumin, is immediately available for use in emergencies.

The fractionation of plasma, having made available fibrinogen, thrombin, and the fibrinolytic enzyme in physical states such that they can be employed in a wide variety of products, opens a new chapter, not only in the large number of surgical uses which are emerging but also in our fundamental understanding of the relation between the

properties of the protein molecules and of the structures that can be prepared from them under controlled conditions.

In 1899 the late Sir William Hardy left the field of histology and developed colloid chemistry in the belief that fundamental advances in our knowledge of the structure of living tissue would have to await advances of our knowledge of the molecules of which it is composed. The time would appear to be at hand when the knowledge of the proteins which Hardy next studied had reached a point where their study in the solid state could form the basis of a new chemical morphology.

THE BLOOD-GROUPING GLOBULINS (ISOAGGLUTININS) OF HUMAN PLASMA

The dangers of transfusion with human blood have largely been eliminated by our increasing knowledge of specific differences in the red blood cells of different individuals. Landsteiner reported in 1900 the presence of agglutinogens in red cells and the corresponding isoagglutinins in human sera. Our present classification of blood types and of red cells distinguishes groups O, A, B, and AB. Other studies have revealed in addition subgroups of type A and AB cells, among them A₂ cells and A₂B cells. The proportion of the individuals in a population belonging to each blood group is approximately as shown in table 5.

The cells of group O blood are not agglutinated by either anti-A or anti-B serum. The blood of such donors is therefore recommended for whole-blood transfusion in military medicine, since no reaction normally occurs regardless of the type of the recipient.

The sera of O type blood as well as of A and B type blood contain isoagglutinins, however. If the plasma of O blood is mixed with the proper proportion of B cells, the anti-B isoagglutinins are removed, leaving the plasma rich in anti-A isoagglutinins. The plasma, or serum, of group B bloods is of course also rich in anti-A isoagglutinins, the plasma or serum of type A blood in anti-B isoagglutinins.

TABLE 5.—*Distribution of population among blood groups*

[Computed from various sources for the population of the United States]¹

Group of red blood cells	Approximate frequency percent	Blood-grouping globulins present in plasma ¹
O	45	Anti-A, Anti-A ₁ , Anti-B.
B	10	Anti-A, Anti-A ₁ .
A ₁	31	Anti-B.
A ₂	10	Anti-B.
A ₁ B	2.6	None
A ₂ B	1.0	None

¹ Omitting certain rare isoagglutinins.

Despite the presence of these isoagglutinins in serum or plasma individuals of all blood groups may be transfused with a pooled serum or plasma. The plasma is rendered safe partly by neutralization within the pool. The specific A and B substances have recently been injected in more or less pure state and shown to increase the titer of the recipient's plasma isoagglutinins.

The isoagglutinins of the plasma are euglobulins which are extremely insoluble in the absence of salt near their isoelectric points. Readily separated and concentrated over thirtyfold with respect to the group-specific serum or plasma from which they are derived, they can be used in the typing of whole blood. Indeed they may be prepared with such high titers and avidity for red cells of the opposite type that gross clumping observable to the naked eye is brought about in a matter of seconds. The blood-grouping globulins are also being prepared from Fraction II+III of group-specific plasma derived from the blood of Red Cross donors and are beginning to be used by the Navy for typing when whole-blood transfusion is indicated.

THE IMMUNE PROPERTIES OF THE γ -GLOBULIN ANTIBODIES OF NORMAL AND CONVALESCENT PLASMA

Many of the antibodies to the variety of infectious diseases to which man has been exposed are γ -globulins. These substances have in the last few years been concentrated and extensively studied not only chemically but also immunologically. The antibodies to many of the common infectious agents to which the population contributing the blood had been exposed have been found. Indeed the large number of blood donors in the Red Cross blood-donor program has made statistical deduction valid and demonstrated that a population shows heightened immunity following an epidemic of a special disease, such as the recent influenza epidemic.

The possibility of utilizing the γ -globulin antibodies derived from pooled normal plasma in the prophylaxis and therapy of any infectious disease depends upon two factors: first, the concentration of specific antibody in the blood of the adult population, which in turn is dependent on previous exposures and on the persistence of these bearers of immunity in the body and their distribution between blood and tissues; and second, the amount of antibody necessary to protect an individual against the infection by passive immunization.

The concentration over the pooled plasma thus far achieved by our fractionation process is approximately twenty-five-fold if we compare plasma with the concentrated solution of immune globulins being made available to the Armed Forces, and through the Red Cross, to public health agencies. As a result titers of certain antibodies, though not necessarily of all, are comparable to those of the corresponding con-

valescent sera. Therefore, in the prevention or treatment of any disease where the value of convalescent serum has been demonstrated, the effectiveness of a concentrate from pooled normal plasma should be investigated. If convalescent serum, or hyperimmune serum is fractionated, still higher antibody titers may be obtained in the concentrated γ -globulins, and their possible value in special cases must also be considered.

The concentrated antibodies, separated from the pooled plasma of a population, offer a means of characterizing the state of immunity of that population as a permanent public health record. Were such records systematically collected and available, it might prove possible to follow the course of epidemics much as the course of a comet may be followed by the photographic records of the skies recorded by modern observatories. Not infrequently the first faint trail of a comet has escaped detection and the origin and course have been understood only because astronomers now map all of the heavens systematically at all times. The systematic collection and preservation as dry white powders of the concentrated antibodies of diverse populations might comparably simplify the analysis of the course of certain epidemics.

TABLE 6.—Average concentration of various antibodies in solutions of normal human serum γ -globulins (Fraction II)

Antibody ¹	Concentration referred to plasma
Typhoid agglutinin, H	19
Mumps, complement fixation	20
Influenza A, complement fixation	18
Influenza A, Hirst test	10
Influenza A, mouse protection	23
Diphtheria antitoxin	25
Streptococcus antitoxin	22
γ -Globulin by electrophoresis	25

¹ Titrations of Enders.

Not all of the antibodies concentrated from human plasma will be of value in the control of disease. However, in the case of measles, where most susceptibles that are exposed are likely to contract the disease, the concentrated antibodies have been employed with great success, either to assure complete protection or by the use of a smaller dose to modify the severity of the disease thus providing a lasting immunity with slight risk of those complications which make measles a serious illness. The record of the use of the γ -globulin antibodies in the prophylaxis of measles is given in table 7.

In the case of many diseases those bearers of immunity which are the antibodies of the blood stream cannot be made available in amounts large enough, or injected soon enough to prevent the onset of the dis-

ease. In others the incidence of the disease in susceptibles is so small that it would be necessary to immunize passively an entire population in order to offer protection to the one in a thousand who might contract the disease. The blood donors for such an undertaking might not always be available, whereas blood donors conscious of the contribution that they were making to the control of other diseases could clearly always be counted on in a society that has contributed as has ours to the blood donor program.

TABLE 7.—*Effect of serum γ -globulin antibodies in measles prophylaxis*

Season	Epidemic	Number of cases	No measles	Mild measles	Average measles
			Percent	Percent	Percent
1942	Philadelphia ¹				
	and Baltimore	891	69	28	3
1942-43	Boston ²	281	59	37	4
1943-44	Scattered ³	111	41	51	8
1943-44	New York ⁴	814	78	20	2
	Total	2,097	70	27	3

¹ Stokes, Maris, and Gellis.² Ordman, Jennings, and Janeway.³ Stokes, Gellis, Janeway, and others.⁴ Rutstein, Greenberg, and Frant.

SUMMARY

The natural functions and therapeutic uses of blood.—Blood is a complex tissue consisting of a fluid part, the plasma, in which cells of various kinds are suspended. Most important among these are the leukocytes or white cells, and the erythrocytes or red cells.

The plasma also is complex. It is an aqueous solution of salts, carbohydrates, and lipids, the latter, for the most part, present in combination with certain of the diverse protein molecules which are the chief plasma constituents.

The various components of the blood stream have such complex interrelations, on the one hand with the tissues, on the other with the external environment, that we may well stress the few systems where an understanding of the mechanism is emerging.

Transport of oxygen by the hemoglobin concentrated in the red blood cells.—The red blood cells have as their prime function the transport to the tissues of oxygen and the removal from the tissues of carbon dioxide and other waste products. The oxygen is transported in combination with the hemoglobin concentrated within the red cell. Other proteins, notably carbonic anhydrase and a complex enzyme system, represent its less copious protein components.

When there is great blood loss from a wound, when a major operation is to be performed, or when the anemia which frequently occurs in convalescence from wounds must be combatted, red blood cells

should be supplied in amounts adequate to restore the oxygen-carrying capacity of the blood.

Maintenance of blood volume by the proteins of the plasma, especially by the albumin.—Plasma, the fluid part of the blood, consists of over 90 percent water and 7 percent protein. Of the proteins, approximately 58 percent is albumin, 14 percent α -globulin, 13 percent β -globulin, 11 percent γ -globulin, and 4 percent fibrinogen.

Plasma is used in military medicine in combatting shock and in the treatment of burns. In burns there is often so large a loss from the body of the diverse components of the plasma that their replacement is necessary. In shock the function of the plasma is largely to restore or maintain the blood volume so that circulation may remain normal. The proteins dissolved in the plasma maintain the volume of the blood by virtue of the osmotic pressure exerted largely by the albumin.

Albumin, the most copious of the plasma proteins, exerts the largest osmotic pressure and thus the largest effect in maintaining blood volume. Its solutions are also the least viscous and for this reason their injection should impose the smallest burden on the heart. Although the smallest of the plasma proteins, albumin does not traverse the blood-vessel walls in appreciable amounts under normal conditions.

Storage and utilization of the proteins of the plasma in equilibrium with the tissues.—The mechanism of control of the blood volume involves the impermeability of the normal blood vessels to the plasma proteins. If plasma proteins are injected in a normal person in excess of need, certain of them leave the blood stream without appearing in the urine and are presumably utilized as a source of energy or new protein or are stored in the tissues. The injection of concentrated serum albumin into the blood stream of a normal man is followed by a rapid redistribution of protein between the blood stream and the tissues. Further investigations are necessary to determine whether this is regulated by colloid osmotic pressure, by subtle changes in the permeability of the blood vessels, or specifically for each species of plasma protein. Clearly there is interaction between the various plasma proteins in the blood and the tissues in health and disease.

Solution and transport of the lipids of the blood in more or less labile combination with α - and β -globulins.—Lipids of diverse kinds are dissolved and transported in the blood, largely in combination, more or less labile, with proteins. Fibrinogen, γ -globulin, thrombin, and albumin are poor, but α - and β -globulin fractions are rich in lipid material. The separation and further purification of these fractions should increase our understanding of their chemical nature, physiological function, and uses in therapy.

Regulation of bodily function by hormones and enzymes of the blood.—The hemoglobin of the red cells, the albumins and lipo-

proteins of the plasma, are present in large amounts. The enzymes, which regulate chemical reactions within the blood, and the hormones, many of which have their origin in the various glands of the body and vary in concentration from time to time, are present in but small amount. Their regulatory functions generally involve other glands or tissues in the body than those in which they originate. The potential value of each in therapy is as a specific concentrate.

Coagulation of the blood by conversion of prothrombin to thrombin and fibrinogen to fibrin clots, fibrin films, or fibrin foams.—The mechanism by which the loss of blood from a wound or cut surface is limited involves a series of proteins. Of these but two are essential to form the blood clot; thrombin, present in the circulating blood as a precursor prothrombin, and fibrinogen, the long asymmetric molecule which is the structural element of the clot.

Fibrinogen and thrombin are both separated in large amounts as products of plasma fractionation. Fibrinogen can be prepared as a thermosetting plastic or combined with thrombin in the form of foams or films.

Fibrin films resemble natural membranes in many respects and have been employed as a protective layer for the central nervous system in the repair of dural defects.

Fibrin foam and thrombin has proven a valuable hemostatic agent in neurosurgery, especially in the treatment of head injuries in this war.

Grouping of the blood by means of the isoagglutinins separated as euglobulins.—The blood of a donor to be used in transfusion must not be agglutinated by, or cause agglutination of, the blood of the recipient. The plasma contains isoagglutinins, proteins, which when separated from type-specific blood have been concentrated over thirty-fold with respect to the plasma and utilized in the grouping of blood for transfusion.

Immune properties of the blood concentrated with the γ -globulins and made available for prophylaxis or modification of measles.—The bearers of the immune properties of the blood are proteins, for the most part γ -globulins. The plasma collected by the American Red Cross that has been fractionated yields albumin, fibrinogen, and thrombin, the blood-typing globulins and the γ -globulins as protein concentrates. γ -globulin, as distributed to the Armed Forces and to public health agencies, through the American Red Cross, is concentrated twenty-five-fold with respect to plasma and has been found to contain a large variety of the antibodies to the diseases common to man.

The studies that have been completed thus far have demonstrated the value of this concentrate in the prophylaxis or modification of measles.

Preservation of the concentrated antibody globulins of the blood as a public health record of the course of epidemics.—Although the concentrated antibodies separated from the pooled plasma of a population will not have value in the prophylaxis or treatment of many diseases, they characterize the state of immunity of that population as a permanent public health record.

The chemical, clinical, and immunological investigations on blood and its derivatives which have been carried forward during this war have resulted in contributions to clinical medicine and surgery, to immunology and epidemiology, to protein chemistry, and to the methodics of the production and control of biological products. They are opening new vistas in our understanding of natural products and natural systems.

ACKNOWLEDGMENTS

This work was originally supported by grants from the Rockefeller Foundation and from funds of Harvard University. It was aided early in 1941 by grants from the Committee on Medicine of the National Research Council, which included a grant from the American College of Physicians. Since August 1941, it has been carried out under contract, recommended by the Committee on Medical Research, between the Office of Scientific Research and Development and Harvard University. The insight of my many fellow members in this department has been immeasurably aided by many colleagues—chemical, clinical, immunological, and pathological—members of this or other universities, of the Armed Forces, of committees of the National Research Council, of the American Red Cross, and of commercial laboratories with Navy contracts for plasma fractionation, who labored with us. Indeed, it would be impossible to list here the very large number of individuals and agencies who have collaborated in this work.

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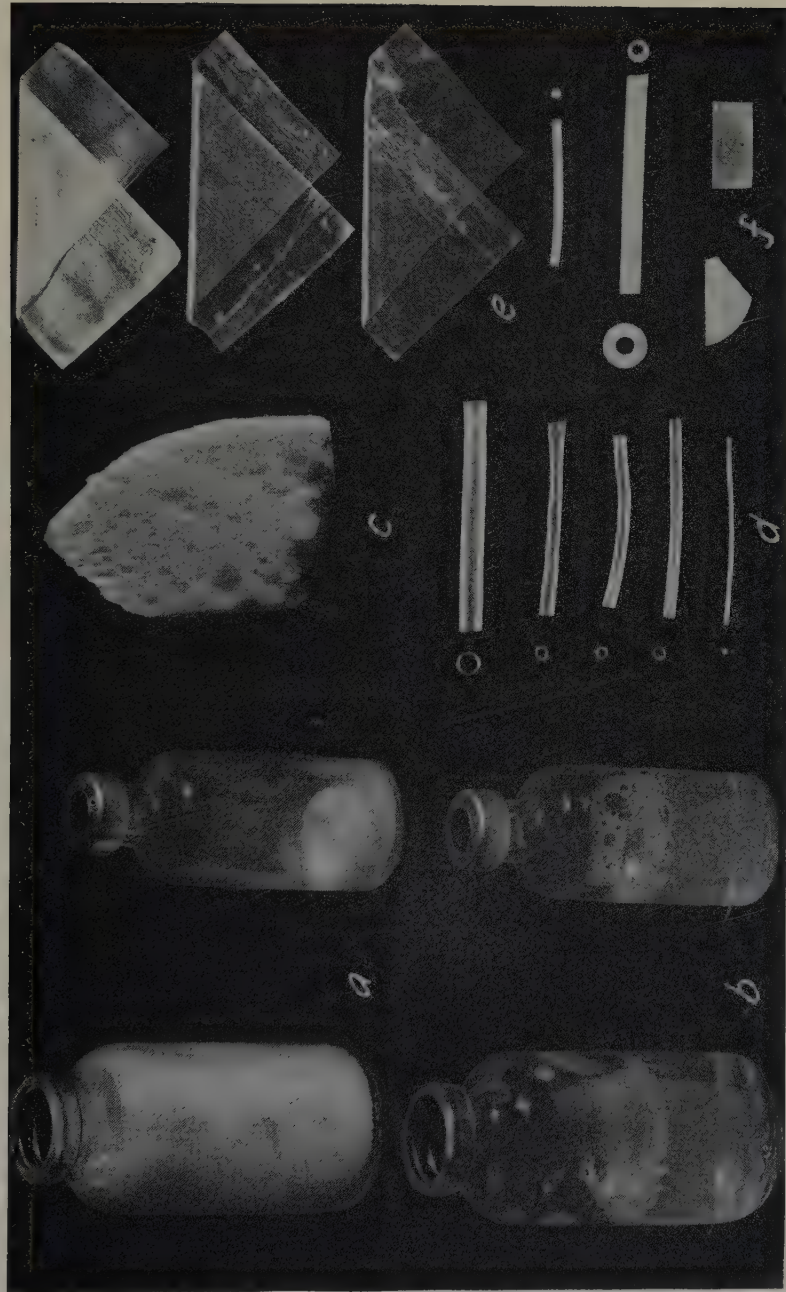
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FIBRINOGEN AND THROMBIN.

a, fibrinogen (left) and thrombin (right) in the dry state; b, fibrinogen (left) and thrombin (right) in solution; c, fibrin foam; d, fibrin tubes; e, fibrin films; f, fibrinogen plastics.

THE MICROBIOTICS¹

By JOHN N. McDONNELL, D. Sc.²

Although very new and little understood, the microbiotic drugs present one of the most striking developments in the history of the health sciences. Within half a decade, an entirely new therapeutic concept has been instituted. An important new group of efficacious drugs has been made available to the medical profession for the eradication of disease.

Many scientists believe, however, that the surface of this new subject literally has only been touched. The microbiotic drugs, and certainly those best known at this time, have far greater possibilities than are appreciated at present.

NOMENCLATURE

From a technical viewpoint, the term "microbiotics" is a misnomer, when applied to the group of chemotherapeutic agents derived directly from micro-organisms. Other descriptive names have been proposed, such as "antibiotics" and others. None of these names is adequate, but for the present they are accepted.

Since the days of Pasteur and Koch in the infancy of bacteriology, the use of the biological products has been the accepted mode of therapy in the prevention and treatment of diseases caused by pathogenic bacteria. Serums and vaccines, toxins and toxoids, and antitoxins have been developed containing, or designed to create, natural antibodies by means of which a patient may be immunized or protected against a pathogenic bacterial infection, or by means of which an infectious disease may be successfully treated. In the past, these natural products have satisfactorily served to reduce the incidence and mortality of certain contagious bacterial and virus-caused diseases. However, they

¹ Reprinted by permission from the American Journal of Pharmacy, vol. 116, No. 11, November 1944, with revisions by the author.

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have been ineffectual against many conditions and in particular against diseases caused by protozoa.

CHEMICALS IN THERAPY

The application of chemical agents to the combatting of disease, of course, is no new development. To a degree, chemicals had been included in the armamentarium of the "medicine man" since time immemorial. The magnificent charlatan, Paracelsus, was the first real exponent of chemicals in therapy. Little was contributed to this field of medical science for hundreds of years, until the discovery of the alkaloid, quinine, in cinchona early in the last century by the pharmacists Pelletier and Caventou, and the isolation of emetine from ipecac. These substances were the first chemical agents effective against the plasmodium of malaria and against amebic dysentery. They represented the beginnings of "chemotherapy," differing from "chemicals in therapy."

CHEMOTHERAPY

Chemotherapy had its true beginning in 1870, when the Frenchman Laveran traveled to Africa in search of a chemical substance which would prove of value in the treatment of trypanosomal diseases such as malaria and sleeping sickness. Choosing arsenic from among the heavy metals, Laveran successfully developed the arsanilates, and for his biochemical discoveries was the recipient of the 1903 Nobel prize. Ehrlich and Robert Koch went further in his researches. From their work came salvarsan and neoarsphenamine. These were the first potent agents against the protozoan disease, syphilis.

Other than the discovery of the arsenicals there were no striking advances in chemotherapy until Hoerlein's researches in 1910, in the use of certain sulfonamide-substituted azo dyes. Even he failed to recognize the value of his discovery.

THERAPEUTIC INDEX

It must be remembered that the value of a chemotherapeutic agent against disease is determined by what is known as the therapeutic index. Pharmaceutical research workers use the mathematical ratio of "high killing power on bacteria or protozoa causing disease" as the numerator of a fraction, the denominator of which is "low toxicity or killing power on animals and patients." Thus many chemicals would be effective against pneumococci of pneumonia or in combatting the organisms causing some other disease, but at the same time they would probably kill the patient. The higher the killing power against micro-organisms and the lower the toxicity, the better the drug.

SULFONAMIDE DRUGS

Until Domagk, 25 years later, experimented with one of the azo dyes developed by Hoerlein, the value of the sulfonamides in the treatment of bacterial infections lay undiscovered. The story of the sulfa drugs is now well known, and the layman is fairly familiar with sulfanilamide, sulfathiazole, sulfadiazine, and even with those not so well known. Many hundreds of different sulfa drugs have been developed and tested in laboratory and clinical trial, but only a few superior ones have been approved and chosen for production. Those which have been employed in the fight against disease have caused a material change in health care and have added nearly a decade to the life span of man.

What is well understood by medical and pharmaceutical workers, and now appreciated even by the general public, is that the "sulfas" are by no means harmless; they are more or less toxic in nature. Some individuals are sensitive to them, showing toxic reactions when they are administered, while it is also possible for a patient to develop this sensitivity. In addition, there are not infrequently individuals who prove resistant to the drugs. In other words, there is a percentage of cases of many of the customarily sulfonamide-amenable diseases where the infection is resistant to sulfonamides. Also, the "sulfas" are not of value in the treatment of protozoan infections.

The primary overenthusiasm for the sulfonamides has subsided, and we now fully appreciate their proper place as potent, efficacious specifics. While they are not a general panacea for all bacterial diseases, they are exceedingly useful against a selected group of infections.

The search for other and better drugs went on, with the emphasis upon those which have as their mode of action a direct toxic effect or metabolic inhibitory effect on the offending organisms.

ANTIBIOTIC CONCEPT

Through the years there existed another concept of antibacterial action in the treatment of disease. As long ago as 1877, when Pasteur and Joubert conducted their immortal experiment on anthrax, they had observed that cultures of anthrax ceased to grow when accidentally contaminated by air bacteria. They also observed that sheep survived when infected with this contaminated culture. This was the first evidence that a substance produced by one micro-organism is capable of arresting the growth of another. Even though Pasteur called attention to this apparent principle, he failed to pursue it further.

At one time it had been believed that the soil was the source of all infections and epidemics. Koch's experiments in 1881 on the survival

rate of bacteria showed that pathogenic organisms die out rapidly in the soil, due to some unknown factor present in soil.

The potentialities of antagonistic mechanisms among the micro-organisms were appreciated by Cantani, who in 1885 endeavored to treat certain diseases by means of known cultures of saprophytic organisms.

PYOCYANASE

Later, many other antibiotics were discovered, including extracts from *Bacillus pyocyaneus*. Pyocyanase has been known since the early nineties, although it was never deemed very effective. It was never obtained in crystalline form, and was employed chiefly in experimental studies, although in Germany since 1930 a pyocyanase ointment has been available for local application on skin lesions resulting from anthrax.

The last step in the series of basic researches which preceded the advent of the recent antibiotic studies was when Vaudremer attempted to treat tuberculosis with *Aspergillus fumigatus* cultures. His unsuccessful work followed preliminary laboratory in vitro tests which had given great promise.

ACCIDENTAL DISCOVERY

Our story really begins, however, in 1928 in the bacteriology laboratory of St. Mary's Hospital, in London. During the routine examination of some culture plates Prof. Alexander Fleming observed entirely by accident a contaminating mold which caused lysis of the staphylococcus organisms nearby. He had observed a phenomenon which had been ignored by countless bacteriologists before and since. Fleming subcultured the mold in broth and found that a strong antibiotic, nontoxic to animals, passed into the broth from the mold. The broth apparently possessed marked inhibitory, bactericidal, and bacteriolytic properties. Fleming coined the name "penicillin" to designate a filtrate of the broth culture of the particular organism which he incorrectly identified as *Penicillium rubrum*. The term "penicillin" has been retained, and while medical dictionaries recommend the pronunciation as "pen'-iss-lin," the majority of scientific workers prefer to use "pen-i-sill-in."

After a year's study, Fleming established the specific activity of penicillin against various gram-positive micro-organisms highly pathogenic to man, including the streptococci, staphylococci, gonococci, pneumococci, and meningococci. He had also discovered that the filtrate was ineffective against many gram-negative cocci and bacilli.

IDENTIFICATION

In 1932 other British workers, Clutterbuck, Lovall, and Raistrick, verified Fleming's experimental reports and with the cooperation of the noted American mycologist Thom, correctly identified the mold as *P. notatum* Westling. Fleming continued his studies but contented himself with reporting that it did not disturb human white blood cells, and that it appeared to have some value for local treatment of dermatologic infections. He employed the filtrate chiefly to inhibit contaminants in the isolation of organisms insensitive to penicillin, such as *Hemophilus influenzae*.

Clutterbuck in 1932 attempted to isolate the active principle from the penicillin filtrate but failed, and with Fleming's reluctant agreement concluded that the substance was too labile. Thus, except for occasional use as a differential culture, Fleming's discovery lay dormant for 10 years.

LYSOSYME

In 1929, the year of Fleming's first report, another British investigator, Howard Florey, and his associates at Oxford began work on lysozyme, an antibiotic substance discovered 7 years before by Fleming, and ultimately crystallized in 1937 by Roberts. During the next decade Florey continued his progress, firmly convinced that somehow an antibiotic would be discovered that would be nontoxic to man yet of value in the treatment of infections. The mechanism of these substances was not clearly indicated, but the principle upon which they acted was generally accepted. Florey studied many organisms but to no avail until 1938 when he directed his attentions to penicillin.

SOIL BACTERIA

During this period, other equally striking work had been conducted in the United States. In the course of studies at the Rockefeller Institute for Medical Research in New York on the virulence of different types of pneumococci, Dubos in 1938 completed a successful search for a specific bacterial enzyme which by decomposing the capsular polysaccharides of the organisms would render the pneumococci avirulent. He believed that micro-organisms existed which would attack other unrelated microbial cells, assuming that all organic matter added to the soil eventually is decomposed by soil micro-organisms. Dubos hoped that living cultures added to soil would develop selective flora capable of attacking certain bacterial species. He was successful in isolating such a material, and prepared from it three active substances inhibitory to gram-positive organisms. They were tyrocidine, gramicidin and gramidinic acid.

TYROTHRICIN, TYROCIDINE, AND GRAMICIDIN

Tyrocidine hydrochloride was first termed graminic acid. A crystalline neutral substance was found to be gramicidin, while gramidinic acid later was found to consist of gramicidin and tyrocidine, and was called by the term now employed, "tyrothricin." All were markedly bactericidal *in vitro* against gram-positive micro-organisms but tyrothricin and tyrocidine were also effective against organisms of the gram-negative group.

Gramicidin proved to be most effective, but caused serious toxic reactions. However, the highly bactericidal effect of gramicidin when injected into experimental animals previously inoculated with cultures of various organisms revived interest in Fleming's penicillin.

Accordingly, Florey, the biochemist, and his Oxford associates, men whose names have since become renowned for their outstanding work, began the systematic study of the new substance, penicillin. Abraham and Chain, and Heatley, all chemists, together with Lady Florey, a physician of competence who was the major contributor to studies on local use of penicillin, all reported on phases of the work.

THE CULTURE

The crude fluid first prepared as an extract of the culture broth of penicillin showed remarkable properties. One part in several hundred thousand and even up to one in a million dilution inhibited growth *in vitro* and *in vivo*, of a number of organisms. It was apparent that here was a potent new agent with, to quote Florey in 1941, ". . . the bacterostatic power . . . as great as, or greater than, that of the most powerful antiseptics known, such as the heavy metal compounds, the acridine derivatives, etc." The causative agents of anthrax, gonorrhea, pneumonia, meningitis, gas gangrene, and a host of other diseases and infections one by one yielded to this new miraculous substance.

PROBLEMS

As yet, the product was not ready for use in the treatment of disease in humans. Two problems confronted the research workers. How should the active substance be extracted? How should it be standardized?

The identification of the physical and chemical nature of the active principle could await the satisfactory resolution of these two earlier perplexing problems, even though the analysis and synthesis of the principle was a task which was of terrific magnitude.

THE OXFORD UNIT

A test for potency was ingeniously worked out by Heatley, under Florey's direction. Fleming's original serial dilution method, similar

to that employed in usual bacteriologic procedures, was empiric and unsuited for exacting work. A modification was developed, using porcelain cups set on agar plates. Heatley defined the unit of penicillin antibacterial activity for the cup method as that amount of penicillin which when dissolved in 1 cc. of water gives a zone of inhibition 24 mm. in diameter, or the amount by serial dilution which when dissolved in 50 cc. of broth completely inhibits the growth of a test strain of *S. aureus*.

The unit of penicillin was accepted by most workers and was named in honor of Florey. However, the latter modestly disclaimed the tribute and proposed instead the now generally accepted "Oxford unit," after its place of discovery. This term is still in use in this country, but because its measure is so small, about 0.6 microgram of penicillin, and because so many are represented in usual therapeutic procedure and industrial production, the British have invented the term "mega-unit" to indicate 1 million Oxford units.

In this country and in England over a score of research laboratories are collaborating in a study of penicillin assays under United States Pharmacopoeial and Food and Drug Administration sponsorship, in order to develop standardized and improved methods.

EXTRACTION

The first method of production employed was the bottle process, where bottles, flasks, or trays were used, requiring thousands of containers to yield any appreciable quantities of the broth culture. This was the sure method and the one employed by all producers in their early programs. Other methods developed later in this country were the trickle method, where inoculated broth flows over stones or chips as an adaptation of the quick vinegar process, and the bran process, where sterile bran is inoculated by cultures, and the penicillin extracted later.

Penicillium notatum grows under both surface and submerged conditions, although different strains are used for the differing processes. The submerged or deep-tank method which is responsible for most of present-day production allows the penicillium-inoculated sterile broth to be aerated for the period of the fermentation cycle, in 1,000-gallon tanks or larger.

The solution to the problem of extraction, which had impeded progress for over a decade, was discovered soon after the unit was developed. It involved the passing of impure acid penicillin broth (pH 2 to 3) from a watery solution into an organic solvent such as ether, chloroform, or amyl acetate, and the subsequent passage of the purified agent again into water, shaken with alkali. This principle, by appropriate cycling and with the aid of further steps in purification with activated carbon, followed by the snap-freezing and desiccation procedure

employed in processing blood plasma, still holds in industrial practice, with some modifications from plant to plant.

CLINICAL TRIAL

A minute quantity of partially purified penicillin was finally obtained, and in England on February 12, 1941, the first human patient was treated. The response was dramatic and extraordinary, even beyond the optimistic hopes of the research team. However, just as its full powers were in evidence, the supply of the drug became exhausted; the patient had a relapse and died. Additional supplies were prepared, and by June half a dozen other patients had been treated, even though the Oxford workers had considerable difficulty in finding subjects. Those eventually turned over to the penicillin team were generally moribund, the most difficult of all possible conditions, where the attending physicians believed that the experimentation could not hurt the patients for whom all hope had already been abandoned. Every one responded, although twice at the peak of success the drug supply again ran out and the patients died.

AMERICAN INTEREST

Faced by all kinds of operational difficulties, shortage of manpower, lack of equipment, and a wide general apathy to their reports, the English research workers remained undaunted. Under the auspices of the Rockefeller Foundation, they came to America, and Florey and Heatley presented their appeal for technical and industrial help to the National Research Council in Washington early in July of 1941. Through the summer months of that year Florey and his associate worked under grants from these bodies and with the research and production staffs of several enterprising American pharmaceutical and chemical houses. They gained the cooperation of Coghill and his co-workers of the United States Department of Agriculture Experiment Station at Peoria, experts in the fermentation field. They were able to develop new culture methods and to find ways of increasing yields. Florey returned to England in September of 1941 to devote his efforts to the improvement of the purification process. Heatley, his fellow worker, remained in this country for a year and assisted in the planning of the first small program of production.

The results obtained in these early months' experiments were even more startling than Florey and Heatley had dared to predict or to hope. American research workers under the direction of the Office of Scientific Research and Development found that their observations more than bore out the early promise of the drug. With renewed enthusiasm, larger-scale production of the drug was planned.

In the interim the United States was plunged into war, but nothing was allowed to interfere, and the development work proceeded unabated.

CLINICAL STUDIES

The first patient to be studied in this country under the extensive research program which has been in force since was treated with penicillin on March 14, 1942, in New Haven, Conn. An advanced case of hemolytic streptococcus septicemia, the response was immediate. A few months later, when additional small quantities of the drug made available from the laboratory-scale production began to provide ample evidence of the almost miraculous powers of this new therapeutic agent, the several cooperating pharmaceutical firms came to the War Production Board with appeals for priority assistance to obtain the exceedingly critical equipment and materials needed for their new pilot plants, which were the next step from research to industrial production.

Approximately 50 different chemical and other substances are required for the preparation of inoculum, culture media, recovery, and testing. Among these are lactose, starch, talc, activated carbon, several acetates, ether, chloroform, lime, sulfuric acid, and a byproduct of starch manufacture, corn steep liquor. Several of these substances are consumed now in quantities totaling millions of pounds a year. The containers and tanks, piping, gages, and meters, vacuum and pressure pumps, refrigeration and sterilization apparatus have represented millions of dollars' worth of wartime critical material. However, immediate cooperation was extended, and one of the most dramatic stories of war production was under way.

COMPLEMENT

Penicillin is not a panacea or a cure-all. It is an effective therapeutic agent and a complement to the sulfonamide drugs. It has some advantages over the latter, but may never replace them. However, medical history will record the coming of penicillin as an important milestone, for this safe drug has proved effective against many pathogens which heretofore proved immune to chemotherapy, and against infections which had shown an all-too-high lethal rate despite amenability to available therapeutic measures. The list of such organisms and infections is impressive and broader clinical investigation will find even greater importance for the new drug just as it is discovering numerous infections against which it is valueless.

ADVANTAGES

Four theoretical advantages of penicillin over the sulfonamides, however, are: (1) it is more potent in inhibiting growth of organ-

isms; (2) its bacteriostatic power is influenced to only a minor extent by the number of organisms; (3) it is not antagonized by breakdown products of tissue autolysis or by exudates (pus); and (4) it is nontoxic.

Penicillin is dramatically effective against a host of killers: Meningitis, pneumonia, tetanus, anthrax, osteomyelitis, syphilis, empyema, cellulitis, diphtheria, gas gangrene, relapsing fever, actinomycosis, puerperal sepsis, and many others. In the treatment of war wounds, penicillin first proved its worth on the bloody sands of North Africa, whence came the early reports to our Army medical staff which prompted them to experiment with it. Out of these studies came the Army's demand in 1943 for penicillin—and as much of it as it was possible to produce! Since then penicillin has earned for itself the equivalent of the Congressional Medal of Honor, for thousands of servicemen's lives have been saved by its wonderful powers, and countless crippled and infected bodies quickly restored to health and usefulness. From the mysterious but important realm of war medicine penicillin emerged as a miracle drug for soldiers and sailors and for civilians alike. However, penicillin is by no means the only successful or promising antibiotic.

CLASSIFICATION OF ANTIBIOTICS

There are many antibiotics. While it is a simple matter to classify antibiotic substances after their chemical structure has been clarified, certain criteria have been developed to enable workers to properly evaluate these agents. The criteria, according to Waksman, are: (1) the organism that produces the substance; (2) the toxicity of the substance and its chemotherapeutic activity; (3) the selective effect of the material upon specific bacteria (this is termed the bacteriostatic or antibiotic spectrum); (4) the chemical nature of the substance (long before the active substance is isolated, microbiologists have a fairly good idea as to its general character); and (5) the mode of action of the substance upon bacteria.

Since an organism may produce several different antibiotics, and in turn several different organisms produce the same type of antibiotic, duplication has been discovered. For instance, a dozen organisms produce penicillin, while clavacin, patulin, and claviformin from different organisms are the identical substance.

Aside from the several known isomers of penicillin, there are a number of other antibiotic agents which deserve mention. Of those which have been mentioned to any extent in the literature, only a few are worthy of comment here.

TYROTHRICIN

Tyrothricin, the combination of gramicidin and tyrocidine, is a highly complex chemical of varying composition obtained from cultures of the aerobic, spore-forming soil bacteria, *Bacillus brevis* strain BG. Its chemical structure is $C_{44}H_{63}N_9O_{11}$ or $C_{74}H_{106}N_{14}O_{19}$. Available as a commercially marketed product, it is used in diluted isotonic solution by instillation, irrigation, or wet dressing. It may be introduced into the body cavities such as the pleural cavity, sinuses, mastoid, and urinary bladder. It is exceedingly toxic in the bloodstream and is not indicated for parenteral injection or oral use. Tyrothricin has been found to be of particular value in treatment of indolent ulcers, abscesses of skin and mucosa, mastoiditis, certain infections of eye, nasal sinus, and pleural cavity, empyema, postoperative infections, and osteomyelitis. It has been found most effective against certain species of staphylococci, streptococci, and similar organisms.

GLIOTOXIN

Gliotoxin was crystallized several years ago, before penicillin, from *Gliocladium fimbriatum*, *Aspergillus fumigatus*, and *Trichoderma* species. It is effective against both gram-positive and gram-negative organisms but is too toxic for therapeutic use. Its chemical formula is $C_{13}H_{14}O_4N_2S_2$. Gliotoxin has been found to be effective against the staphylococci, streptococci, and *Diplococcus pneumoniae*.

FUMAGACIN, FUMAGATIN, AND ASPERGILLIC ACID

Aspergillic acid is a substance derived from *Aspergillus flavus*, having the chemical structure of $C_{12}H_{20}N_2O_2$ without sulfur in the molecule. It has a limited range of effectiveness against both gram-positive and gram-negative bacteria.

Fumagacin, or helvolic acid as it is also called, is similar in action to penicillin. It has an indefinite chemical formula with either 32 or 53 carbon atoms, and is lacking in both nitrogen and sulfur. Being water-insoluble in nature and less active, it is less valuable even though it is generally effective against gram-positive organisms, similar to the action of penicillin. It is derived from *Aspergillus fumigatus*. Also obtained from the same organism is fumagatin, $C_8H_8O_4$, which has limited sensitivity and therapeutic value.

OTHER KETONE COMPOUNDS

These ketone antibiotic compounds have been crystallized and obtained in pure form. Several others are of lesser significance, such

as penicillic acid ($C_8H_{10}O_4$) from *P. cyclopium* and *P. puberulum*; kojic acid ($C_6H_6O_4$); puberulic acid ($C_8H_8O_6$); and puberulonic acid ($C_8H_4O_6$).

CLAVACIN

A significant ketone antibiotic is clavacin, which has many aliases, such as patulin, claviformin, and clavatin. Obtained from *Aspergillus clavatus*, *P. patulum*, and *P. claviforme*, it has the formula $C_7H_6O_4$. Great enthusiasm was evidenced at one time in Great Britain because of its reported value against both gram-positive and gram-negative organisms and for its apparent action upon the secondary organisms which complicate the common cold. Later experimental use by other workers failed to substantiate the early expectations that it would prove a specific for the common cold, but the subject is still an open one with many authorities, according to Raistrick.

Chaetomium cochliodes is the source of chaetomin, which has also been isolated but never purified. It has limited usefulness but may ultimately prove of more value. Citrinin, $C_{13}H_{14}O_5$, is a quinone from *P. citrinum* and from other species of *Aspergillus*. It is not as active as the other antibiotic agents and is more toxic.

ACTINOMYCIN

Of the various species of organisms from which antibiotics may be developed, the actinomyces are the most promising, for over one-fifth of all these species are capable of producing antibiotic substances of some type.

One of the most promising of the group is actinomycin A. Obtained from *A. antibioticus*, it is a pigmented ring compound with the formula $C_{41}H_{56}N_8O_{11}$. Although it is toxic to animals, its complex nature provides possible avenues of approach whereby the chemist may substitute in the formula and bring about a reduction in toxicity and a further increase in physiologic activity.

Various actinomyces species produce actinomycetin, a polypeptid of indefinite composition which is comparatively nontoxic but of only limited activity. It acts more or less as a proteolytic enzyme.

NOTATIN

Penicillin B, notatin, and penatin are terms used to describe a glucose aerohydrogenase from *P. notatum*. It has only slight activity and specificity against a limited number of organisms. None of this entire group of antibiotics, with the exception of penicillin and tyrothricin concentrate, have achieved sufficient recognition to warrant commercial production for therapeutic use.

STREPTOTHRICIN AND STREPTOMYCIN

However, another new antibiotic which is already in the clinical research stage of development is streptothricin. This substance is derived from *A. lavendulae* and is effective against both gram-positive and gram-negative organisms. It possesses the properties of an organic base. Streptothricin is antimicrobial rather than merely antibacterial for it has shown value against various pathogenic fungi and higher forms. In addition to equaling the value of penicillin against gram-positive organisms (with the exception of streptococci), it has a significant value against such gram-negative organisms as the colony-typhoid and salmonella groups. Other than use in the treatment of infected wounds and burns, it has a limited future.

Streptomycin, a closely related compound, is similar in activity and has been shown to have far less toxicity. Developed by Waksman and his associates at the New Jersey Agricultural Experiment Station, streptomycin is derived from cultures of *Actinomyces griseus*. It has shown remarkable properties in combating both gram-positive and gram-negative organisms, particularly against hitherto resistant bacillary conditions of the latter group. This new drug has been studied by Herrell and Heilman, of the Mayo Clinic, and by Reimann and others at Pennsylvania.

Effective against *Klebsiella pneumoniae*, Friedlander's infection, mixed bacillary and salmonella infections, and in particular against *B. tularensis* of tularemia, streptomycin has proved exceedingly valuable in the eradication of *Eberthella typhosa* in typhoid fever. In early reports based on laboratory in vivo experiments and on remission of lesions in clinical treatment of *Mycobacterium tuberculosis* infections, streptomycin has been found to be a valuable agent. It has also given early promise in treatment of veterinary infections such as fowl typhoid and brucellosis.

Streptomycin is not a replacement for penicillin, but will be a valued supplement to that drug and to the sulfonamide chemotherapeutic agents. It has great promise as a therapeutic agent of the future.

As far as the related antibiotics are concerned, three substances are now recognized as valuable in the treatment of human infections. One is derived from soil bacteria, the other two from molds. Tyrothricin has sufficient value to be retained as a therapeutic agent for immediate nontissue penetration contact bactericidal action, particularly for operational usage. Streptomycin is already proved of value for its effectiveness against the gram-negative organisms. Penicillin will still remain the drug of greatest promise, at least until some as yet undiscovered substance appears to displace it.

PENICILLIN THERAPY

To return to the subject of penicillin, a pertinent fact concerning its action is that, just as certain sulfonamide-fast bacteria are sensitive to penicillin, so there has been reported evidence of organisms which are persistently resistant to penicillin. The cause may be natural, acquired by prolonged contact, or due to small colony variants. So far as is known, no cases have been reported yet where sulfonamide-fast organisms have proved resistant to penicillin, and vice versa, which is gratifying.

Any list of pathologic conditions and states in which penicillin was known or believed to be effective must of necessity be considered incomplete. Certainly present research programs and the results which will be gained from usage of the drug will undoubtedly broaden its field of indications. It is already evidenced that where it is equally as efficacious as other measures, including sulfonamides, economic factors and mode of administration govern usage.

A concise and helpful report on indications for penicillin was prepared in 1944 by Dr. Chester Keefer, chairman of the committee on chemotherapy of the National Research Council, and consultant to the Office of Scientific Research and Development, for the War Production Board's Office of Civilian Penicillin Distribution. Based on accumulated experience, it was found that penicillin was the best therapeutic agent available for the treatment of certain conditions, as follows:

All staphylococcus infections with and without bacteremia: Acute and chronic osteomyelitis, carbuncles—soft tissue abscesses, meningitis, cavernous or lateral sinus thrombosis, pneumonia—empyema, carbuncle of kidney, wound infections—burns, and endocarditis.

All cases of clostridia infections: Gas gangrene, malignant edema.

All hemolytic streptococcal infections with bacteremia and all serious local infections: Cellulitis, mastoiditis with intracranial complications, i. e., meningitis, sinus thrombosis, etc., pneumonia and empyema, puerperal sepsis, peritonitis and endocarditis.

All anaerobic streptococcal infections: Puerperal sepsis.

All pneumococcal infections of meninges, pleura, endocardium. All cases of sulfonamide-resistant pneumococcal pneumonia.

All gonococcal infections, especially those complicated by arthritis, ophthalmia, endocarditis, peritonitis, epididymitis. All cases of anthrax; chronic pulmonary suppuration in which surgical treatment is contemplated. All meningococcal infections failing to respond to sulfonamides. All cases of bacterial endocarditis due to susceptible organisms.

Originally listed in a second group, where penicillin has also been found effective, but its position not definitely defined, were syphilis, bacterial endocarditis, and actinomycosis. It is now generally recognized that syphilis and bacterial endocarditis are proper indications

for penicillin therapy. Recently added was diphtheria, especially in horse-serum-sensitive patients.

Keefer listed in a third group certain conditions of questionable value, in mixed infections of the peritoneum and liver in which the predominating organism is of the gram-negative flora, such as ruptured appendix, liver abscesses, urinary-tract infections and in rat-bite fever due to streptobacillus moniliformis.

Penicillin was contraindicated (meaning that the drug was of no value and where administration might cover up symptoms or forestall other proper therapeutic measures, not that any danger was present from toxicity) in the following cases because it is ineffective:

All gram-negative bacillary infections: Typhoid—paratyphoid, dysentery, *E. coli*, *H. influenza*, *B. proteus*, *B. pyocyaneus*, *Br. melitensis* (undulant fever) *P. tularensis* (tularemia), *B. friedlander*.

Tuberculosis, toxoplasmosis, histoplasmosis, acute rheumatic fever, lupus erythematosus diffuse, infectious mononucleosis pemphigus, Hodgkins' disease, acute and chronic leukemia, ulcerative colitis, coccidiomycosis, malaria, polio, myelitis, blastomycosis, nonspecific iritis and uveitis, monilliasis virus infections, cancer.

ADMINISTRATION

Penicillin must be administered in rather large doses at first to create a satisfactory blood level, and for parenteral administration repeated administration is required thereafter at 4-hour intervals or continuously because it is readily excreted and only sparingly absorbed. The drug is inactivated to some extent when administered orally. However, it has been reported that if large enough quantities are given orally, adequate blood levels may be attained. Various methods of protecting orally administered penicillin have been successfully demonstrated and products such as tablets and lozenges are available.

Penicillin is supplied in ampuls and vials of 100,000 or 200,000 Oxford units each, and when kept at refrigeration temperature will retain its potency for over 2 years. Inasmuch as penicillin is soluble, it may be dissolved in small amounts of sterile, distilled, pyrogen-free water, or in sterile, normal saline solution. When large-unit sizes are being used in hospitals, the contents of the vial should be dissolved so that the final concentration is 5,000 units per cc. This solution should be stored under aseptic conditions in the ice box. Kirby and others have reported that solutions will retain their potency for several weeks and even when kept at room temperature it was found that potency remained for more than a week.

For intravenous use the dry powder is dissolved in sterile physiological salt solution in concentrations of 1,000 to 5,000 units per cc. or higher, for direct syringe injection. It may be dissolved in sterile saline or 5 percent glucose at 25 to 50 units per cc. for constant intra-

venous therapy. For intramuscular injection the total volume of individual injections should be small, i. e., 5,000 units per cc. of saline; for topical application, solutions, in salt solution of 250 units per cc., with the volume increased to 500 units per cc. where resistant or intense infections appear. The powdered form is irritating to wound surfaces and should not be used.

Romansky and Rittman reported on the use of a sterile mixture of 4 percent beeswax in peanut oil as a base for penicillin. This prolongs and increases absorption, maintaining penicillin levels for as long as 8 hours. Greater economy and effectiveness may be attained by such measures if they prove practical. Cholesterol is also used.

There are three common methods of administration for penicillin: intravenous, intramuscular, and topical. Subcutaneous injections are painful and should be avoided. Repeated intramuscular injection may be tolerated less well than repeated or constant intravenous injections, but frequently the intramuscular route is the method of choice.

The dosage of penicillin varies from one condition to another, and depending upon the patient. The objective is to bring the infection under control as quickly as possible.

PROCESSES

The production of penicillin by several basic processes has been engaged in by over a score of industrial firms. In all these, pure culturing and aseptic handling is essential. Where contamination occurs the penicillium fails to produce penicillin. From seed-culture stage to large-volume production, either by flasks or deep-tank method, is a step which has tasked the ability of the entire industry. The details of the processes vary from one process to another and need not be discussed here. Suffice to say that the final product is a sterile, dry, yellowish powder. It is a relatively pure product, marketed for use as the sodium or calcium salt. Pure penicillin is a white crystalline substance, and does not require refrigeration.

POTENCY

The present penicillin product has a potency of more than 1,200 Oxford units per milligram, and it is rapidly approaching chemical purity, the potency for which has recently been agreed upon, at the meeting of international experts on penicillin in London under League of Nations sponsorship, as 1,666 Oxford units per milligram. It has been observed that the purer the product the less likelihood of reactions, and while some of the pure salt has been prepared, mostly for use as a reference standard, clinical trial has not yet determined whether any therapeutic value is lost in the complete purification

process. It is expected that a pure crystalline penicillin salt will eventually be marketed.

Recent work on penicillin has indicated that there are at least four types of penicillin: penicillin F (British I), penicillin G (or II), allopenicillin (III) or factor X, a more stable, more readily crystallizable and perhaps more clinically effective substance, and a factor K, or penicillin K. Wintersteiner isolated pure crystalline penicillin, but the search for its chemical identity and for methods of syntheses was shrouded in wartime secrecy.

PRODUCTION

The dramatic story of the battle for production of penicillin also had to await the end of the war for the telling. Only 400 million units of penicillin had been produced experimentally prior to June of 1943, and little more than 20 billion units during the balance of the year. Twelve months later, 20 tremendous plants located from coast to coast were pouring out increasing quantities of the drug. They represent an investment of almost 30 million dollars in critical equipment and materials. During the month of October 1944 over 200 billion units were produced—in 1 month well over 10 times the total production of all of last year, yet the total product weighed not much more than 10 avoirdupois pounds. (By March 1946 the monthly production reached 2,000 billion units.—*Author's note.*)

RELEASE

At first most of the material available was supplied directly to the armed services, with only limited amounts of penicillin released for domestic civilian use and small quantities for urgent foreign needs. During the months prior to April of 1944 small quantities of penicillin had been allocated by the War Production Board to the Office of Scientific Research and Development for a program of clinical research under the direction of Dr. Chester Keefer of Boston, and the treatment of urgent cases.

On May 1, 1944, the War Production Board had available a small surplus of penicillin over and above military and research requirements, and under the direction of the Drugs and Cosmetics Branch and the Penicillin Producers' Industry Advisory Committee, a program of allocation for civilian hospitals was inaugurated. The Office of Civilian Penicillin Distribution of the War Production Board was organized by the writer as Director, and was located in Chicago. A limited supply of penicillin was released for use in accordance with the recommendations formulated on the basis of the clinical experience by OSRD and NRC workers. The method was to distribute to

over 1,000 selected hospitals serving as depots in the United States, Alaska, Puerto Rico, Hawaii, and the Virgin Islands. These received quotas for each month, and from this supplied their own needs and those of the nearby hospitals and practitioners. The list was expanded to include over 2,700 depot hospitals. On March 15, 1945, sufficient stocks had been accumulated and production levels created, and on that date penicillin was released by the War Production Board for distribution through normal trade channels to the professions for general use.

The cost of penicillin, when first quoted, was \$20 per vial of 100,000 units, and that was acknowledged to be far below actual cost. Now it reaches the civilian hospital at less than 65 cents per vial, and is supplied to the armed services at a much lower cost. No doubt the price will go much lower as the present production goals are neared.

CONCLUSION

Today penicillin is an accepted essential in the armamentarium of materia medica of the physicians in America. The search for newer and better therapeutic agents in the field of antibiotics continues unceasingly. From the research laboratories and manufacturing plants of American pharmaceutical and chemical industry has come an amazing record of achievement which ranks with the great scientific and industrial advances of all time in the history of the United States and of the world. It has been an unsurpassed contribution to the healing professions and to the welfare of mankind.

A BRIEF SUMMARY OF THE SMITHSONIAN INSTITUTION'S PART IN WORLD WAR II¹

INTRODUCTION

With the onset of World War II, so many new agencies were created to cope with problems facing the Government and the Army and Navy that for a time the chief concern of the Smithsonian was to find its place in the scheme of war activities, and how best to make its resources count in the Nation's total war effort. Many research organizations with physical and chemical laboratories were immediately called upon for aid in urgent wartime investigations, and their problem was mainly how to accomplish promptly all that they were asked to do. At the Smithsonian, where the sciences dealt in—chiefly anthropology, biology, geology, and astrophysics—were of less obvious war usefulness, and where the facilities consisted of museums, art galleries, and small laboratories, staffed by highly specialized scientists in the disciplines just mentioned, the problems were to find its field of war service and to make its resources known.

The Secretary of the Institution, sensing this situation shortly after Pearl Harbor, met it by appointing a War Committee to canvass the Institution's possibilities and to recommend specific lines of action. As a result, a large part of the effort of the staff was diverted to work connected directly or indirectly with the war, and the Smithsonian Institution was found to be an essential cog in the great war machine in Washington. Although its role was inconspicuous as compared with those of the large war agencies, nevertheless it was found to offer services not readily available elsewhere—services whose lack might well have led to costly mistakes and delays. The war was to an unprecedented degree a war of science, utilizing not only the physical sciences, but also anthropology, biology, and geology—branches of science with which the Institution is particularly concerned. Its staff of highly trained specialists in these and other fields, as well as its location near the nerve centers of the Army and Navy and the other war

¹ Prepared by a committee appointed by the Secretary of the Smithsonian Institution, Dr. Alexander Wetmore, consisting of Carl W. Mitman, Head Curator of Engineering, U. S. National Museum, and Webster P. True, Chief of the Editorial Division, Smithsonian Institution, in accordance with the request of the late President Franklin D. Roosevelt, through the Bureau of the Budget, that all agencies prepare an objective statement of their participation in the war effort.

agencies, made the Institution a ready source of quickly needed technical information and hence a valuable arm of the war services in Washington.

A brief résumé of Smithsonian war work will not only serve as an archival record, but might also conceivably be of value in connection with certain postwar activities.

WAR COMMITTEE

The Secretary's intent in creating a War Committee was that it should serve as the agent and the rallying point of the entire staff of the Institution. The personnel of the committee was selected to represent the various phases of Smithsonian interests. The chairman, Carl W. Mitman, represented engineering and industries; the secretary, William N. Fenton, anthropology; Herbert Friedmann, natural history; Loyal B. Aldrich, the physical sciences; and Webster P. True, the publication and information branch of the Institution. The committee's instructions were brief and unencumbered by a multiplicity of detailed directions. It was given the responsibility of doing a job and left free to do it in whatever manner the turn of events indicated. In effect, its sole purpose was to receive suggestions, canvass possibilities on its own initiative, and recommend actions that would promote the effectiveness of the Institution in the war effort.

The administrative simplicity of this method of adapting Smithsonian activities to wartime needs enabled the War Committee to cut red tape and act promptly on all proposals from within the Institution or from without. Of course, its authority was limited to the making of recommendations to the Secretary, but it attempted through the wording of its recommendations to produce a simple "yes" or "no" decision. If the decision was "yes," the committee kept in close touch with the approved project and aided whenever possible in promoting its success.

The War Committee proceeded as follows: Recognizing that it was merely the agent of the entire staff, it first invited suggestions from every member as to how best he or the Institution as a whole could serve in the Nation's war effort. It next sifted the suggestions and considered first those that appeared to be widely recognized as desirable and suitable. Each project approved by the committee was submitted to the Secretary as a separate recommendation to avoid complicating the decision on approval. When suggestions from the staff were all in hand and given full consideration, the committee itself made a systematic canvass of the Institution's resources, facilities, and outside contacts to be sure no possibility of action had been overlooked.

The main principles guiding the committee in its consideration of possible activities were four: They should be of definite war value; they

should fall within the Institution's capabilities and resources; they should be as far as possible along the lines of its normal work in order to avoid complete disruption of its unavoidable curatorial and research duties; they should avoid duplication of work being done or proposed by other agencies.

The committee made 23 definite recommendations for action to the Secretary, and most of these were approved and carried out. A few were rejected for administrative reasons, and 2, although approved in principle, were not made effective because of lack of agreement among those whose cooperation was necessary for their development.

In May 1944 the committee came to the conclusion that all possible means of making the Institution useful in the war had been canvassed and advertised, and it therefore asked to be dissolved. In a letter expressing appreciation of the value of the committee's work, the Secretary assented.

The headings that follow are not the individual recommendations of the War Committee, but are the topics under which the Institution's war work falls.

TECHNICAL ASSISTANCE TO ARMY AND NAVY AND OTHER WAR AGENCIES

Probably the Smithsonian's most effective contribution to the war was its ability to answer urgent calls from the Army and Navy for information in a variety of fields—mainly anthropology, biology, geology, geography, physics and astrophysics, engineering, textiles and fibers, and woods. Many of the requests were for information that had only an indirect war connection, but others led straight to the fighting fronts and had a direct bearing on the progress of the war. Among these latter requests were calls for means of identification of various kinds of disease-bearers, such as mosquitoes, rats, and mollusks; for reports on geography, peoples, and other features of areas ahead of the actual fighting; for transliteration of Chinese and Japanese names on maps of war areas; for preparation of a survival manual for aviators and other personnel stranded in unfamiliar areas; and for many other items of equal importance.

These calls for technical information had begun to reach the Institution even before the creation of the War Committee. Recognizing the interest and importance of keeping a record of this war service, the committee formulated a standard card on which each staff member was asked to enter the agency making the request, the name of the inquirer, nature of the information wanted, whether or not it could be furnished, and the name of the staff member. These cards as received by the committee were kept constantly under lock and key, as

the character of some of the inquiries could in the wrong hands provide clues to future military operations.

The inquiries were handled in various ways, but in general, staff members were left free to deal directly with the official making the inquiry in order to avoid administrative complications and the inevitable delays resulting therefrom. When the staff member called knew the answer to only one phase of the problem, he supplemented his information by referring the inquirer to others on the staff who had the knowledge needed to complete the story. Other requests came to the staff through the Ethnogeographic Board, discussed later in this statement, through Army and Navy liaison officers, and through the War Committee. As inquiries were answered to the satisfaction of the Army, Navy, or war agency officials, the Smithsonian's resources of specialized knowledge became more widely known, and requests for information steadily increased in number.

The number of recorded requests from Army, Navy, and war agencies for the war years was 1,509; the number of such requests for Smithsonian publications containing needed technical or other data was 1,186—a total number of 2,695 calls upon the Institution's resources. Furthermore, many calls for one reason or another did not get recorded, so that the real total would go considerably higher. Such statistics, of course, serve only to show the volume of the Smithsonian's contribution in this field, not the time or effort expended, or the value of the work. Many calls were for "spot" information and could be answered immediately; others required a varied amount of research; and many led to detailed written reports with illustrations.

It would serve no useful purpose to list here all the recorded requests for information; instead there will be tabulated merely the more or less popularized headings under which they have been roughly classified, with an example or two under each to show their great diversification. These headings, with examples, are as follows:

Anthropology, General

Examples: Information on the current political situation in Peru with special reference to Axis espionage—for a war agency.

Request for the anthropology laboratory to make two busts of an average youth of 19 for use in designing naval aeronautical equipment.

Ethnology

Examples: Data on the language and ethnology of the people of the islands off Formosa—for the Army.

Description and pictures of native Burmese houses—for the Army.

Physical Anthropology

Examples: Information on the scientific concept of race for use in an anti-Axis propaganda motion picture designed to neutralize fallacious racial ideas—for a war agency.

Methods of distinguishing physical features of Japanese and Chinese for use in pamphlet to be distributed among troops—for the Army.

Astronomy

Examples: All available data on astronomical "seeing" in various parts of the world—for the Navy.

Intensities of moonlight and twilight—for the Army.

Biology, General

Examples: Information on marine life of western Alaska—for the Army.

Conference on the application of our knowledge of marine organisms to certain war problems—for the Navy.

Birds

Example: Information on homing and migration. Specimens of hawks for class use in training men as to hawks that destroy pigeons—for the Army.

Fishes

Examples: Data for report on what should be in a fishing kit for life rafts—for the Army.

Data on poisonous fishes and on the distribution of sharks—for the Navy.

Insects

Examples: Numerous conferences on insect vectors of disease—for Army and Navy.

Information for a list of insect pests of importance to troop movements in Europe—for the Army.

Mammals

Examples: Distribution and identification of Asiatic rats—for the Army.

Physiology of diving mammals—for the Navy.

Mollusks (including Shipworms)

Examples: Numerous conferences on shipworm problems—for the Navy.

Numerous conferences on mollusks that serve as intermediate hosts for Oriental parasites—for Army, Navy, and a war agency.

Fouling Organisms

Example: Numerous conferences on organisms that foul ships' bottoms and their identification—for the Navy.

Plants

Examples: Numerous conferences on poisonous and edible plants of the Pacific war area—for the Army and Navy.

Identification of quinine-producing plants and others of medical importance—for a war agency.

Reptiles

Examples: Data on poisonous snakes of New Guinea and adjoining islands—for the Army.

Information on sea snakes occurring near South Pacific islands—for the Army.

Boats

Examples: Sources of photographs of types of small craft in legitimate trades off Atlantic coast—for the Navy.

Lists of names of animals and birds, and Indian names for use in naming Naval vessels.

Camouflage

Examples: Criticism and revision of list of plants to be used for camouflage purposes in coastal installation—for the Army.

Photographs for use in camouflage instruction—for the Army.

Cork, Fibers, and other Strategic Materials

Examples: Information on types of fibers for cordage—for the Army.

Rattan substitutes in West Africa—for the Navy.

Editorial Service

Examples: Request to check manuscript of training manual for botanical information—for the Navy.

Editing and supervising compilation of a glossary of Chinese geographical and topographical terms on maps—for the Army.

Engineering

Examples: Construct mapping device in engineering laboratory—for a war agency.

Photographs of helicopters and autogiros—for the Army.

Geography

Examples: Numerous requests for information, conferences, reports on geography, weather, peoples, etc., of many Pacific war areas.

Geology, General

Example: Suggestion of training centers in areas in the United States with physiographic features of certain foreign countries—for the Army.

Mineralogy

Examples: Information on selenium resources—for the Navy.

Information on optical fluorite and calcite—for a war agency.

Health

Examples: Lectures to class in tropical medicine at Army Medical School.

Information on what is most needed for medical relief to Russia—for a war agency.

Library Service

Examples: Much specialized bibliographic assistance to Army and Navy investigators.

Personnel

Examples: Request for the name of a qualified expert to direct production of cordage fibers in Latin America—for a war agency.

Names of Arctic, Tropic, and Desert specialists—for the Army.

Photography

Example: Conferences on underwater photography—for the Navy.

Physics

Example: Information on ultrasonics—for the Navy.

Survival

Examples: Information on food sources in the Indo-Pacific area—for the Army.

Means of subsistence for stranded aviators in China and Mongolia—for the Army.

Technology

Example: To make experimental delayed time devices—for the Army.

Translation

Examples: Translation of 1,400 Chinese place names on a map—for the Army.

Translation of 257 pages from Japanese—for a war agency.

Wood Technology

Examples: Numerous identifications of foreign woods for war purposes—for Army and Navy.

Information on proper grouping of true mahogany and African mahogany in lumber schedules—for a war agency.

These examples were chosen more or less at random from the record cards under the various headings and serve only to show the scope of the questions asked by Army, Navy, and war agencies. For some of

the headings there are hundreds of recorded inquiries, whereas for other topics with which the Institution is known not to be particularly concerned, only a few appear. The four subjects that show the largest number of inquiries are biology, anthropology, geography, and wood technology.

GEOGRAPHIC ROSTER

The War Committee, shortly after its appointment, realized that the first step toward a utilization of Smithsonian resources in the war effort would be a systematic record of the geographic and other specialized knowledge of all members of the staff. A questionnaire was submitted to each member asking him to list his travel and field experience, his knowledge of languages, and his available photographs of regions other than the United States. This material was tabulated on cards by areas of the world, and to it was added the individual's personal history and his special knowledge. From the card file, a report was prepared under the title "Roster of Personnel, World Travel, and Special Knowledge Available to War Agencies at the Smithsonian Institution."

At the time the report was completed, the Ethnogeographic Board (discussed in the next section) was being organized. As the Board was to serve as the clearinghouse for just such information, the Smithsonian roster was turned over to it, serving as the nucleus for its larger file of such data. Dr. William N. Fenton, a member of the War Committee who had prepared the Smithsonian roster, was designated by the Secretary to serve as research associate of the Ethnogeographic Board, and he at once proceeded to expand the roster to include personnel of the Department of Agriculture and other personnel records that were available. The file grew steadily until it eventually covered some 4,500 specialists whose knowledge covered every part of the globe.

The Director of the Board was enabled through this file, indexed by names and countries, to locate promptly upon request from the Army and Navy persons with special information, maps, photographs, and knowledge of languages of any particular foreign region. Army and Navy officers and civilians representing the war agencies used the file constantly.

ETHNOGEOGRAPHIC BOARD

The Ethnogeographic Board was originally proposed by the National Research Council as a means of bringing together in one place all the known resources of specialized and regional knowledge so urgently needed by the Army and Navy, particularly in the early days of the war. The Smithsonian War Committee, hearing of the plan and recognizing in it an extension of the service the Institution itself

was rendering, recommended to the Secretary that the Institution take a part in sponsoring the Board and offer immediately partial financial support and office space in the Smithsonian Building. The offer was promptly made with the result that the Institution joined with the National Research Council, the American Council of Learned Societies, and the Social Science Research Council in setting up the Ethnogeographic Board with offices in the Smithsonian Main Hall.

The six members of the Board were chosen jointly by the four sponsoring institutions. They served as a policy-making body and acted in an advisory capacity to the Director, who conducted the business of the Board. The Director selected was Dr. William Duncan Strong, who obtained leave from Columbia University to accept the wartime post. Three members of the staff of the Smithsonian Bureau of American Ethnology were assigned to assist the Director, and the specialized knowledge of the entire Smithsonian staff was available to him. Army and Navy liaison officers were in constant touch with the Board.

As a separate history and analysis of the work of the Board has been written, no detailed account will be given here. It will only be stated that the Board proved almost immediately to fill a vital place among the Washington war agencies. Besides making available to the Army and Navy the great regional file of specialists able to assist in the solution of problems relating to all parts of the world, the Board produced on request numerous special reports on particular regions for use in planning military operations, and served as a real clearing-house for "spot" information in many different fields.

By July 1944 the most urgent needs of the armed forces for regional and related information had been met, and at that time Dr. Strong went back to Columbia University to resume his duties as professor of anthropology. The Board was kept in operation and continued to fulfill its function on a reduced scale under the guidance of Dr. Henry B. Collins, Jr., of the Bureau of American Ethnology.

WAR RESEARCH WORK

Although the Institution has no large laboratories that could be used for extensive war investigations, nevertheless its smaller laboratories and shops and the specialized knowledge of its personnel were made available for whatever researches were requested by Army and Navy officials. For example, the facilities and staff of the Astrophysical Observatory, including the Division of Radiation and Organisms, were occupied for a considerable time with research on the heat radiation properties of various cloths, pigments, and other materials used for war purposes, and on the deterioration of impregnated cloth, cardboard, and other materials used by the Navy. A number of special instruments were developed and constructed for the Navy, and

considerable work was done on the problem of a simple, portable device for obtaining drinking water from sea water.

In geology, one staff member was in the field continuously throughout the war years directing an investigation, in cooperation with the United States Geological Survey, of Mexico's resources of strategic minerals. Another member took part in an economic survey of the ore and mineral deposits of northern Mexico, and later investigated Devonian stratigraphy in Illinois in connection with oil resource studies.

Much of the work in the field of biology was in the nature of continuous assistance to war agency personnel through identification of specimens, instruction in various fields of medical biology, conferences on recognition and control of harmful organisms, reports on the occurrence and identification of strategic plant material, and other similar activities.

In anthropology, staff members prepared a number of reports and articles involving research on the native peoples of various war areas at the request of Army and Navy intelligence officers. Studies of Arctic clothing were made for the Army Quartermaster Corps, based on the extensive collections of Eskimo garments in the National Museum. For use in the design of oxygen and gas masks, data were worked out and supplied to the Army on the variations of the human head and features.

These are but a few of the war research problems investigated by the Smithsonian, but they will serve to show the type of work the Institution was qualified to do. The problems came in various ways: Through personal contacts with Army and Navy officials, through the War Committee or the Ethnogeographic Board, or through direct approach by the agencies with urgent problems to solve. Technical assistance was also given by making laboratories and personnel available for the working out of mechanical problems. Thus, the engineering laboratory and its staff worked on several devices that were under study by the National Inventors' Council, building models and mock-ups for test purposes.

INTER-AMERICAN ACTIVITIES

With the outbreak of war came the realization that Western Hemisphere solidarity was not only desirable but essential to the safety of the countries of both continents. It became an urgent duty of the United States Government to take the lead in promoting good will, cooperation, and a feeling of unity among all the American republics. The Smithsonian Institution was qualified to take part in such a program through its long years of friendly contact with scientists and scientific institutions in South and Central America, Mexico, and the West Indies, and its continuous program of field explorations in those

regions. The units of the Institution most concerned with inter-American cooperative work were the National Museum, the Bureau of American Ethnology, and the Institute of Social Anthropology.

All the field work of the National Museum during the war was diverted to Latin America. Expeditions during the war years included an investigation of ancient skeletal collections in Peru; a wide-ranging reconnaissance of Mexico's resources of strategic minerals; a study of the geology of Sonora, Mexico, as a basis for the location of mineral deposits; field researches in Brazil on mammals that serve as hosts of vectors of transmissible diseases; conferences with museum staffs in Brazil, Uruguay, and Argentina on problems concerning crustaceans and other invertebrates; collecting and identifying plants of little-known regions of Venezuela; studies of the plants and mammals of Colombia; exhaustive researches on the snakes of Mexico; collecting and studying the insects of Colombia and Jamaica; and a comprehensive investigation of the fishes of Venezuela as a scientific aid to that country. Another phase of the Museum's inter-American work was the identification of large lots of biological material received through scientific and medical organizations and private individuals in the other American countries. The Museum also made available for the use of visiting scientists from the other American republics its laboratory, study, and library facilities. A wartime publication project of the National Museum is the very large checklist of coleopterous insects of all the Western Hemisphere to the south of the United States. The first three parts of this work have been printed and the remaining parts are in preparation. When completed, the checklist will be an indispensable tool for all entomological workers in those regions.

The Chief of the Bureau of American Ethnology, M. W. Stirling, has for several seasons conducted archeological expeditions to southern Mexico under the joint sponsorship of the National Geographic Society and the Smithsonian Institution. Many interesting and important discoveries have been made, the collections going to the National Museum in Mexico City. The Mexican Government has evinced much interest in the expeditions and has facilitated the work whenever possible. The Bureau is publishing the monumental "Handbook of South American Indians," a project undertaken by the Smithsonian Institution as a part of the State Department's program of inter-American cultural cooperation. Under the editorship of Dr. Julian H. Steward, the Handbook progressed steadily, and at the end of 1945 volumes 1 and 2 were in type, volumes 3 and 4 were in the hands of the printer, and the remaining volume was practically completed. The preparation of articles on the various groups was kept on a truly cooperative plane, as 50 percent of the contributors to the Handbook were scientists of the other American republics.

Dr. Steward also provided the initiative for the formation of two other agencies designed to improve cultural relations among the various countries of the Western Hemisphere, namely, the Inter-American Society of Anthropology and Geography, and the Institute of Social Anthropology. The first of these, founded with the assistance of the Coordinator of Inter-American Affairs, was organized for the purpose of bringing together the scholars of the Western Hemisphere who are working on problems of the cultures, both aboriginal and contemporary, of the Americas. The Society, supported entirely by dues of the members, has a membership of more than 700 representing nearly every country in the Hemisphere. A journal entitled "Acta Americana," with articles in English, Spanish, and Portuguese, records the activities of the Society and the findings of the individual members.

The Institute of Social Anthropology is a joint project of the Smithsonian Institution and the State Department's Interdepartmental Committee on Cooperation with the American Republics. Set up as an autonomous unit of the Bureau of American Ethnology and financed by the State Department, the Institute cooperates with institutions in other American countries in training personnel to carry out anthropological research through university instruction and field work. One of the cooperative programs of the Institute is with the Escuela Nacional de Antropología of the Instituto Nacional de Antropología e Historia of Mexico. This program involves teaching anthropology, cultural geography, linguistics, and related subjects at the Escuela and field research among the Tarascan Indians of the State of Michoacán in Mexico. Another project is under way in Peru and yet others are being formulated. The Institute has already issued two publications bearing on its work and two others are in the hands of the printer.

Other examples of Smithsonian wartime efforts to improve cultural relations with the other American republics are the doubling of its exchanges of scientific and governmental publications with those countries through its International Exchange Service, and the showing of a number of special exhibitions of the work of Latin-American artists by the National Collection of Fine Arts, another branch of the Institution.

It will be seen that these Inter-American projects are for the most part extensions of the Institution's normal activities in research, exploration, and other fields. The emphasis was placed on building good will with our neighbors to the south, and whenever possible the work was planned on a cooperative basis so that the peoples of the two continents might feel that they had an equal interest in the furtherance of cultural activities.

WARTIME PUBLICATIONS

The outstanding wartime service of the Institution in the field of publication will be found in its new series entitled "War Background Studies." With the war reaching to remote parts of the earth, particularly in the Pacific region, and with many of the Institution's scientific staff knowing these areas through first-hand experience and study, the Smithsonian found itself in an excellent position to make this specialized knowledge of direct use in connection with the war. It was decided to restrict the series largely to the Pacific area, as it was felt that the countries of the European theater of war were too well known to need further discussion in such a pamphlet series.

The series was begun with a general paper entitled "Origin of the Far Eastern Civilizations," in which the prehistory and early history of the Far East form a backdrop for the peoples of today. This was followed by a series of papers on the peoples, geography, history, natural history, and other features of the Soviet Union, the Philippines, Polynesia, Japan, Siam, New Guinea, Alaska, the East Indies, Micronesia and Melanesia, Burma, India, French Indochina, China, and the Aleutian Islands. These were interspersed with papers on general topics related to the war, such as "The Evolution of Nations," "Are Wars Inevitable?" "The Natural-history Background of Camouflage," "Poisonous Reptiles of the World," and two on special war areas not in the Pacific region, namely, "Egypt and the Suez Canal" and "Iceland and Greenland."

As soon as the new series became known the papers were in wide demand, especially from Army and Navy units and individuals, for whom the series was primarily intended. The papers were at first distributed free to all applicants, but it became apparent that the Institution's limited printing funds would not permit the continuance of this unrestricted distribution. After July 1944 civilians requesting copies were asked to pay approximately cost price, but Army and Navy personnel continued to get them without charge.

When Army and Navy intelligence and education officials became familiar with the contents of the War Background Studies, they began to order special printings of the various papers for orientation and educational use within the armed forces. At the end of the war more than 400,000 copies had been thus used in addition to the Institution's own distribution of over 225,000 copies, a total of over 625,000 books. Through various sources it has been learned that the series was used by the Army and Navy in orientation courses, in military government schools, and in general educational programs among the military and naval personnel; by civilian agencies, as textbooks in university courses, as the basis for lectures and club discussions, and in numerous libraries as a part of their special war literature service.

With the realization that many thousands of Army and Navy personnel were stationed in far-away areas not actually in combat zones, the Institution compiled and printed a Field Collector's Manual in the hope that its study and use might provide a welcome recreational activity. The pocket-size manual gives detailed instructions as to the preparation and preservation of specimens of mammals, birds, fishes, insects, and many other things that might come under servicemen's attention. A thousand copies were given to both Army and Navy to acquaint them with its contents, and more copies were later acquired by both services.

Many Smithsonian publications issued prior to the war proved to be of direct war usefulness, particularly its series of tables—physical, meteorological, and mathematical—which for many years have been in constant use in laboratories and research centers. Several thousand copies of the Meteorological Tables were requested by Army and Navy officials. Two Smithsonian papers were especially useful to Army and Navy medical units, one on the feeding apparatus of biting and sucking insects affecting man and animals, and another on the molluscan intermediate hosts of the Asiatic blood fluke. Several hundred copies of each of these papers were required by the armed services.

MISCELLANEOUS WAR SERVICES

The Smithsonian library is one of the largest collections in the world of the proceedings and transactions of scientific societies and organizations. During World War II, in which science played so large a part, there was constant library research by many officials of the Army, Navy, and civilian war agencies, and in the resources of the Smithsonian library were found answers to many urgent scientific problems. The library staff aided such investigators to the limit of its ability and enabled them to find many elusive bits of information needed to complete the picture of world-wide operations. Special bibliographies were compiled by the library staff, and many specially needed works were located. A mimeographed statement on the resources of the Smithsonian library was distributed through the Ethnogeographic Board to key men in the Army, Navy, and war agencies to facilitate the finding of source material.

In addition to the wartime activities at the Institution itself, its administrative officers also served on governmental boards and committees, thereby making their experience available to an ever-widening circle. The Institution was represented in this way on the National Advisory Committee for Aeronautics, the Public Buildings Administration, the National Resources Planning Board, the Interdepartmental Committee on Cooperation with the other American republics, and others.

The Institution put on a number of special wartime exhibits, including several representing the war activities of our allies, one of identification models of Allied and enemy aircraft, several regional exhibits covering areas involved in the war, one showing the development of modern weapons, and one illustrating life-saving and rescue equipment used by the Navy.

In the matter of special services to members of the armed forces, the Institution's efforts included the opening of its buildings all day Sunday for the benefit of the many servicemen in and around Washington; the furnishing of free postcards in color to servicemen, with writing and mailing facilities available for their use; and servicemen's guided tours on Sundays through the Museum exhibits in cooperation with the U. S. O. and under the supervision of Frank M. Setzler, Head Curator of Anthropology of the National Museum.

SUMMARY

After the outbreak of war, as it became apparent that the Smithsonian Institution was not to be assigned definite war duties, the Secretary planned a deliberate effort to make its resources of the greatest possible usefulness in the prosecution of the war. He appointed a War Committee, which canvassed every facility of the Institution and recommended lines of action. A roster of the geographical and specialized knowledge of every member of the staff was compiled. Thousands of requests for technical information from Army and Navy were handled, both directly by the Institution's staff and through the Ethnogeographic Board, a clearinghouse set up jointly by the Smithsonian and three other agencies. Members of the scientific staff undertook a number of war research projects, and the engineering laboratory assisted the National Inventors' Council in working out certain inventions. The Institution took an active part in the Government's program of improving cultural relations with the other American republics. A number of publications having a direct war bearing were issued, the most outstanding being the new series of War Background Studies, of which the Army and Navy used over 400,000 copies. Other wartime activities included special library service to war agencies, service on wartime committees, special war exhibits, and special features for members of the armed forces. No particular administrative problems were involved in the Smithsonian's war activities, as most of them were merely extensions of its normal peace-time work. It is the hope and belief of the Institution that no possibility of war service was overlooked and that the Smithsonian's contributions were of measurable value in the Nation's all-out war effort.

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